A.N.E.

JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XXV. FEBRUARY, 1913. No. 1.

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A THEORY OF SURFACE CONDENSATION.

BY D. B. MORISON, ASSOCIATE.

A research on the condensation of steam in surface condensers was commenced at the Armstrong College, Newcastle-on-Tyne, England, in 1904, and in 1906 Dr. Weighton read a paper before the Institute of Naval Architects which contained much instructive data on the subject. The condenser tested was of the original 1904 "Contraflo" type, now obsolete, and in cross section was a wedge cut into three superposed parts. The object of the design was to establish initial uniformity of steam distribution over the tubes throughout their entire length and to maintain uniformity of flow through a passage of decreasing cross section from the steam inlet to the air outlet. The condenser contained only 100 square feet of surface and was so small that the effect of air concentration could only be ascertained by adopting a relatively long path of vapor flow, hence the long wedge divided into three sections.

Dr. Weighton's experiments with this condenser definitely establish the correctness of the principle, but subsequent ex-

perience with large condensers showed that the reversal of the steam flow caused air eddying whilst uniformity of flow over the surface was difficult to maintain.

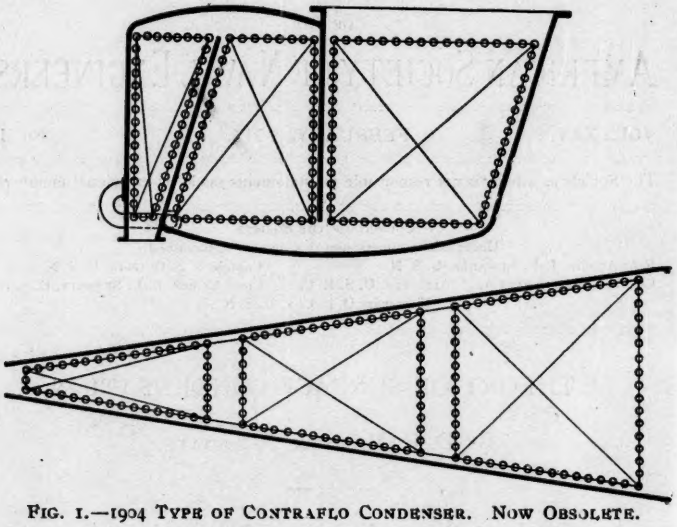


FIG. 1.—1904 TYPE OF CONTRAFLO CONDENSER. NOW OBSOLETE.

Patient and prolonged research with various designs resulted in the ultimate adoption of multiple-wedge chambers arranged in parallel within a shell, the flow through the wedges being continuous and the proportions of the wedges such as to reduce steam turbulence at entry, facilitate gradual air collection during flow, and promote air concentration at exit. In this way what is now known as the Contraflo Kinetic Condenser was evolved, and as a result of the systematic testing of a considerable number of high-vacua condensers of this type the writer ventures to submit the following theory whereby a solution of the problem of surface condensation may be found along the lines of elementary first principles.

If no air were present in condensers the problem of surface condensation would be simplified, as no air pump would be required, but in practice the crucial problem in the attainment of high vacuum is how best to treat the small quantity of air

which normally enters the condenser with the steam, and make at the same time provision for dealing with the much larger quantities which result from accidental and inevitable leakage into the vacuum system.

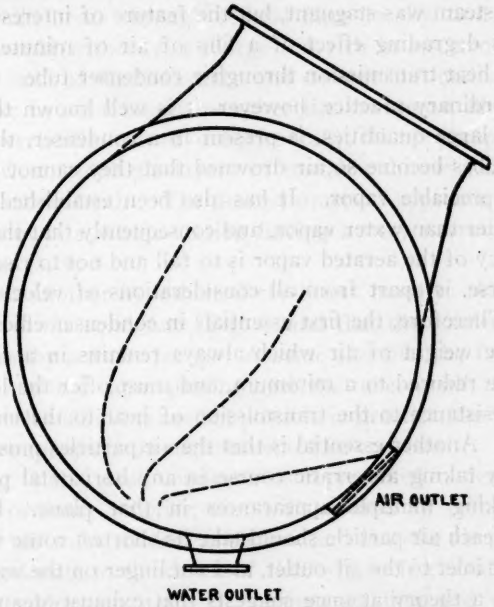


FIG. 2.—CONTRAFLO KINETIC CONDENSER, 1910.

In 1905 Mr. J. A. Smith, of Australia, carried out some very valuable experiments to determine the effect of air on heat transmission through a condenser tube. He found broadly as follows: That the presence of air in quantities which might have been deemed insignificant can, in fact, become the factor limiting the efficiency of a whole steam plant. For instance, air equal in pressure to only one-twentieth of an inch by the mercury gage would, at 90 degrees F. reduce thermal transmission some 25 per cent., whilst three-twentieths of an inch would lower it about 50 per cent. The experiment further demonstrated that a condenser which is dealing with steam at 90 degrees and the tubes of which are smoth-

ered with air at a partial pressure of three-tenths of an inch will require two and a-quarter times more cooling surface than when dealing with airless water vapor at the same temperature. These experiments should be viewed qualitatively, as the steam was stagnant, but the feature of interest was the serious degrading effect of a film of air of minute thinness on the heat transmission through a condenser tube.

In ordinary practice, however, it is well known that when air, in large quantities, is present in a condenser, the lowermost tubes become so air drowned that they cannot condense any appreciable vapor. It has also been established that air is heavier than water vapor, and consequently that the natural tendency of the aerated vapor is to fall and not to rise. This, of course, is apart from all considerations of velocity of entry. Therefore, the first essentials in condenser efficiency are that the weight of air which always remains in a condenser must be reduced to a minimum, and must offer the least possible resistance to the transmission of heat to the circulating water. Another essential is that the air particles must neither eddy by taking an erratic course in any horizontal plane nor by making multiple appearances in that plane. In other words, each air particle should take its shortest route from the exhaust inlet to the air outlet, and not linger on the way.

Such a theory at once suggests that exhaust steam should enter a condenser as a uniformly moving column, the sectional area of the column being the plan area of the top row of tubes. If such a plan area were continued unchanged the condenser would be a rectangular box, and the air-pump suction would naturally be in the middle of the base. Assuming hypothetical stability, the condenser becomes filled with an infinite number of horizontal superposed films, the top film containing the least amount of air and the bottom film the greatest. The contained air in such a condenser is the sum of the particles in all the films, and as the real function of an air pump is the withdrawal of the greatest quantity of air of the greatest density which is normally contained in the condenser, it is obvious that the lowermost film or the film which is richest

in air, should be preferentially and wholly withdrawn by the air pump, and the entire withdrawal of the superposed film should follow, and so on.

But in such a rectangular box in such conditions the air pump would break through several films locally, and consequently would withdraw a charge less rich in air, and would leave the bulk of the lowermost and densest film undisturbed.

Suppose by some means or other the lowermost film were disposed vertically instead of horizontally, the air pump would then draw not multiple layers of unstable thinness, but one layer of stable depth. The nearest practical approach to this requirement is a wedge section having a very narrow outlet as in Figs. 3, 4, 5.

Suppose another hypothetical condition, namely: *that there is no air in the condenser,* Fig. 3, and that the condensate is withdrawn by a water pump. Assume also that the frictional resistance of the vapor passing over the tubes is *nil,* then, although such conditions are not possible in practice, the vacuum and the temperature throughout would be constant.

In Fig. 4 the same condenser is represented under conditions of ordinary practice, viz: with air and air pump. Assume the air to be shaded, as shown, and that the air pressure is proportionate to the depth of tint. If such a condenser is working under conditions of vacuum stability and with no eddying, then the shading would be lightest at the top and darkest at the bottom; the temperature would be highest at the top and lowest at the bottom, and the charge of air withdrawn by the pump at each stroke would be the densest the condenser contains.

Now, suppose in Fig. 5 the conditions to be identical in every respect with those in Fig. 4, except that in Fig. 5 a lighter shade is maintained at the bottom of the condenser, say, for example, a shade corresponding to the shade in the middle of Fig. 4.

(NOTE.—It must be remembered that the quantity of air admitted with the exhaust is precisely the same in both Figs. 4 and 5, but that the normal weight of air which remains in

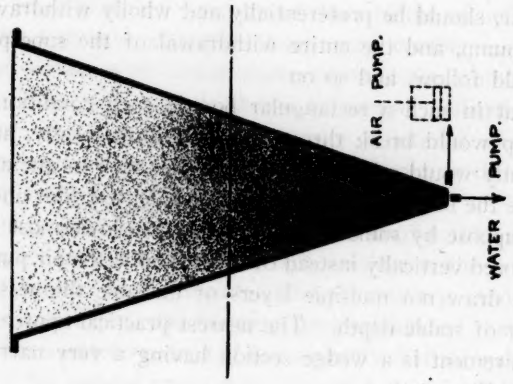


FIG. 4.

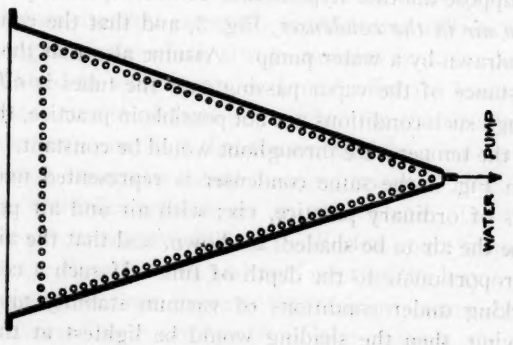


FIG. 3

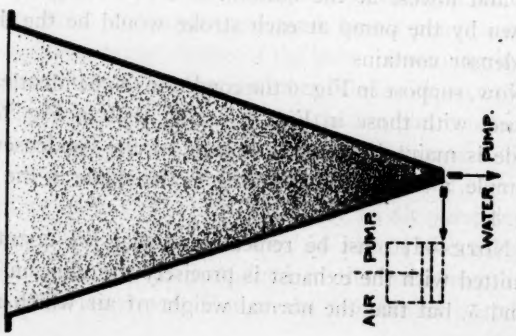


FIG. 5

the condenser, Fig. 5, is less than that which remains in Fig. 4, by the amount below the center line in Fig. 4.)

The general technical effect produced in Fig. 5 is that every single tube in the condenser has been relieved of a definite amount of air insulation; more heat is transmitted to the condensing water, so that the final temperature of the condensing water is increased, the condenser is cooled, and the vacuum rises.

It is the condenser which is primarily responsible for the high vacuum attainable under these conditions, as by means of the wedge the air is disposed in pressure gradations which reach a maximum at the outlet from the condensing chamber. It is, moreover, highly essential that the disposition of the gradations at the outlet shall be such that a given weight of air presents as small a surface area and as great a depth as the practical requirements of sufficiency of passage permit. Concurrently the air pump is enabled to maintain such an air condition within the condenser that the air pressure at the air outlet is minimized, the air insulation within the condenser is reduced, and the greatest amount of heat is transmitted to the condensing water. It should again be noted that when once the vacuum in each condenser, Figs. 4 and 5, has become stable then each air pump normally withdraws exactly the same weight of air per unit of time, namely: the weight which enters each condenser with the exhaust steam, but in Fig. 4 the condenser has degraded itself until the pressure is reached which its air pump demands in order to withdraw the air.

The relation between a condenser and an air pump can thus be seen. For example, the ability of a condenser to create a very high vacuum must always remain latent if it is worked in conjunction with an inefficient air pump. What is required is such combined unit efficiency as will enable the very highest vacuum to be maintained that the condenser is capable of producing.

The next important consideration is the proportion of the wedge. The thin end presents no difficulty. It should be so narrow that the air forms a strip or plug of such stability

that eddying or disturbance is impossible. In practice the width is determined by the necessary allowance for the passage of air and condensate. The desideratum at the top of the wedge is to stop eddying. This can best be achieved by arranging the wedges as, for example, in Fig. 2.

It should now be evident that the often misunderstood problem of intermediate collection of condensate and the consequent influence on its temperature is in reality simple.

Referring again to Figs. 3, 4 and 5, no air being present in Fig. 3, there is equality in temperature throughout the condenser, and on the formation of drops of condensate they splash over tubes in their descent and are alternately cooled by the tubes and heated by the vapor until, on arrival at the bottom, they are approximately at the same temperature as that corresponding to the vacuum.

In Fig. 4, air being present, the temperature gradually decreases from the top to the bottom, and therefore the drops of condensate when falling from tube to tube must pass through a cold-air zone, with the result that the final temperature is less than that corresponding to the vacuum. Therefore the temperature of the condensate, relatively to that of the vacuum, depends on the temperature of the air zone through which it falls, and consequently on the shape of the condenser.

Almost any condenser lends itself to the intermediate collection of condensate, as some must fall on the sides and thus short circuit the colder air zones. But something more is required; overcooling of the condensate must be avoided, and yet the temperature of the air should be brought near to that of the cooling water. In Fig. 2 the multiple-wedge chambers discharge into an air receiver which may or may not be fitted with tubes, but for the highest vacuum tubes are very valuable, as they enable the temperature of the air to be brought to within a few degrees of that of the condensing water. It should be noted that this air-cooling effect is initiated in the base of the multiple wedges, where many of the tubes are entirely sheltered from the streams of falling condensate, and

is carried to its logical conclusion in the final air-cooling chamber.

Another natural phenomenon of which, in condenser design, little or no intelligent advantage has been taken, is the kinetic energy of the inflowing steam, and yet the utilization of this energy for promoting a higher efficiency of air pump has a direct bearing on the production of high vacua. Fig. 6 is a cross section of a pear-shaped condenser in a turbine-driven battleship.

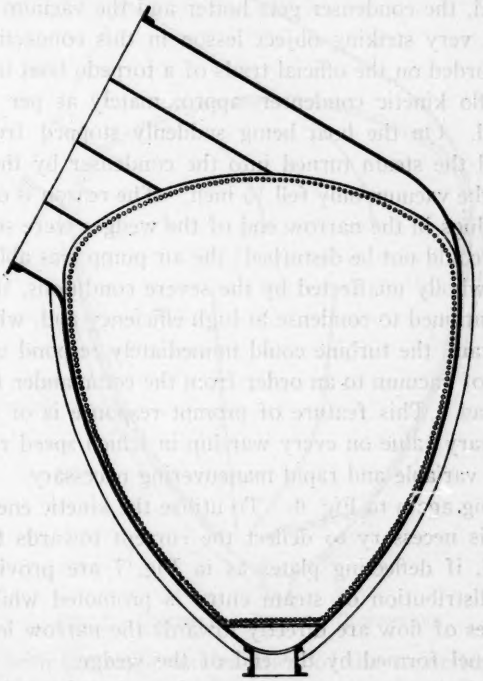


FIG. 6.

The steam inlet is strengthened by the usual plates which divide the inlet into a number of passages through which the steam enters the condenser at a velocity of say 500 feet per second. This high-velocity current strikes the curved side

of the condenser and sets up such a whirling effect that air eddying is promoted, and consequently the weight of air normally contained in the condenser is rapidly increased simply because the air pump withdraws not what it should, but what it can.

A silent blow-off from the boilers into an ordinary condenser produces this effect, as the local inflow sets up abnormal whirling—the air pump withdraws less air and more vapor, air accumulates in the condenser, the heat transmission is reduced, the condenser gets hotter and the vacuum rapidly falls. A very striking object lesson in this connection was lately afforded on the official trials of a torpedo boat in which a Contraflo kinetic condenser, approximately as per Fig. 2, was fitted. On the boat being suddenly stopped from full speed and the steam turned into the condenser by the silent blow-off the vacuum only fell ½ inch. The reason is obvious. The air plugs in the narrow end of the wedges were so stable that they could not be disturbed; the air pump was able to do its work wholly unaffected by the severe conditions, the condenser continued to condense at high efficiency and, what was all important, the turbine could immediately respond under a full head of vacuum to an order from the commander for full speed ahead. This feature of prompt response is of the utmost military value on every warship in which speed requirements are variable and rapid maneuvering necessary.

Referring again to Fig. 6. To utilize the kinetic energy of inflow it is necessary to deflect the current towards the air outlet and, if deflecting plates as in Fig. 7 are provided, a uniform distribution of steam entry is promoted whilst the stream lines of flow are directly towards the narrow longitudinal channel formed by the end of the wedge.

The effect is to compress the air into the air outlet and thereby to permit the air pump to maintain in its air-suction system a minimum of air pressure. Consequently the weight of air normally contained in the condensing chamber and the air-insulating effect on the heat-transferring efficiency of the tube surface are so reduced that a given quantity of con-

densing water at a given temperature will carry off more heat, the temperature of the condensing chamber will be lowered and the vacuum will be raised. To put the matter briefly, by the utilization of the kinetic energy of the inflow the air pump is able to maintain a lighter air shade at its suction (Fig. 5) and consequently there is less air insulation in the condenser.

It is obvious that the resistance offered by the tubes to-

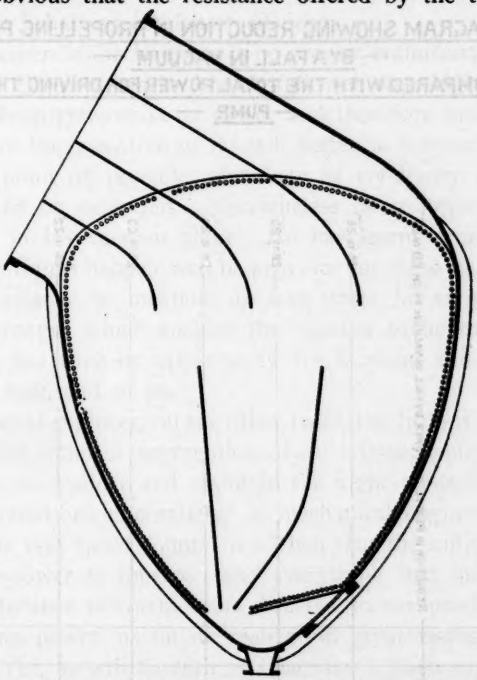
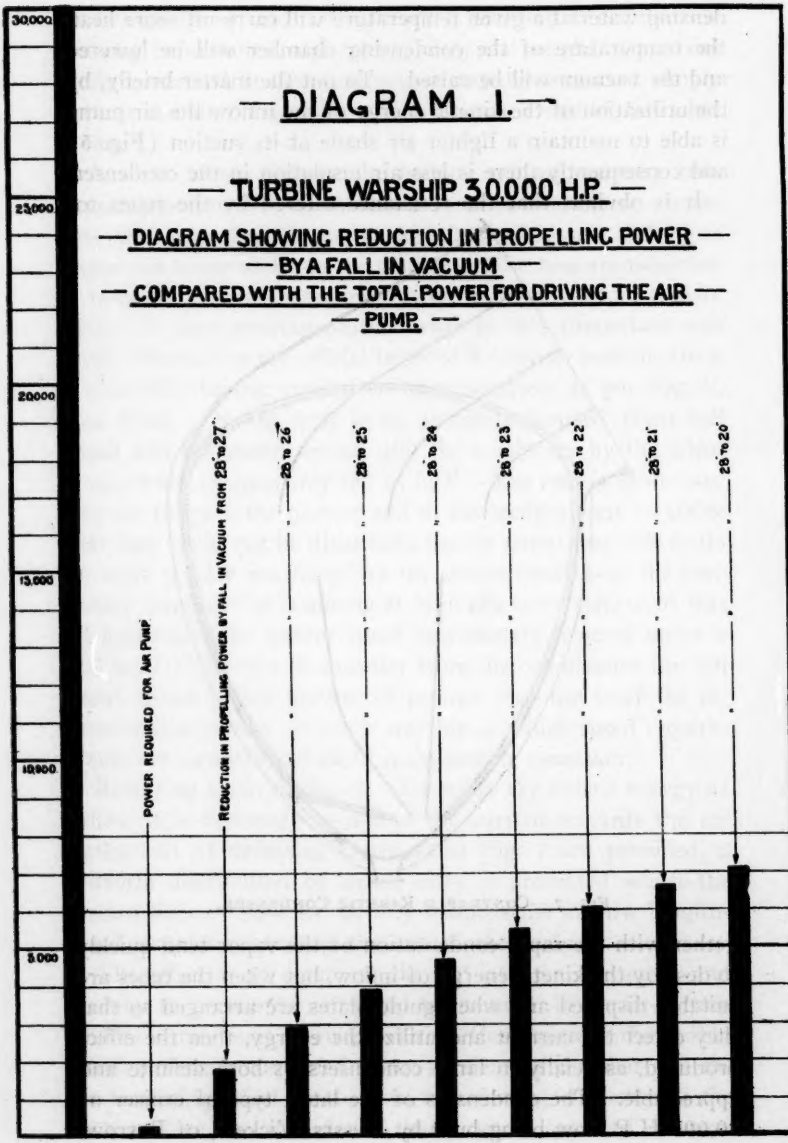


FIG. 7.--CONTRAFLO KINETIC CONDENSER.

gether with the rapid condensation of the vapor tend quickly to destroy the kinetic energy of inflow, but when the tubes are suitably disposed and when guide plates are arranged so that they direct the current and utilize the energy, then the effect produced, especially in large condensers, is both definite and appreciable. The condensers of the latest type of cruiser of 30,000 H.P. now being built by Messrs. Vickers, of Barrow,


30,000
23,000
20000
13,000
10,900
5,000
DIAGRAM I.
TURBINE WARSHIP 30,000 H.P.
DIAGRAM SHOWING REDUCTION IN PROPELLING POWER
BY A FALL IN VACUUM
COMPARED WITH THE TOTAL POWER FOR DRIVING THE AIR
PUMP.
POWER REQUIRED FOR AIR PUMP
REDUCTION IN PROPELLING POWER BY FALL IN VACUUM FROM 28 to 27
28 to 26
28 to 25
28 to 24
28 to 23
28 to 22
28 to 21
28 to 20

are of the Contraflo kinetic type and embody the above construction.

As a warship problem, the production of the highest possible vacuum has a peculiar fascination by reason of its effect on the amount of power which can be obtained from a given quantity of steam. This effect is, of course, well known, but when graphically set forth as in Diagram 1, it makes a strong appeal on behalf of condenser efficiency.

In commercial circles there is no greater enthusiast than the electrical engineer, as he knows full well that high vacuum means cheap generation of power and therefore more profit. With him the incentive to do still better is forever present; and no point of possible advantage in condenser design is overlooked or neglected. Nevertheless he is never without margins in his vacuum plant. He has learnt from experience that things happen, and he provides for those happenings. If, for instance, an insidious air leak starts, his air pump has an air margin which enables the vacuum to be maintained until he has time or opportunity for locating and stopping that air leak, and so on.

The naval engineer, on the other hand, has little if any margin in that complex aggregation of mechanism which in wartime has to produce and maintain the highest possible power under conditions unparalleled in mechanical engineering. It is in war that speed counts; it is then that the military value of horsepower is supreme, and everything that human skill and endurance can achieve is directed to the production of maximum power, as on its realization great issues may depend. Yet, as will be seen in Diagram 1, even superhuman efforts may be neutralized in a turbine-driven warship by the loss of one single inch of vacuum. The demand not only for the production but for the maintenance of high vacuum on warships is therefore imperative in the interests of military efficiency.

THE DESIRABILITY OF USING HIGH MEAN REFERRED PRESSURES.

By E. M. Bragg, Associate.

The statement has been made, several times of late in the Journal, that an economical engine must have a large number of expansions. It seems desirable to the writer to present a few facts upon the other side of the question.

In the past too much importance has been assigned to the question of the number of expansions. Experimental results have shown that more attention should be given to the mean referred pressure employed, and to the cut-offs in the I.P. and L.P. cylinders, if economy of steam is desired.

In a paper read before the Institute of Engineers and Shipbuilders, in Scotland, and printed in Vol. 50, 1906–7, Mr. R. Royds made certain statements concerning the best mean effective pressure for any given condition, and these statements have been concurred in by most of the men who have had experience in testing engines. These statements are as follows:

(1) The higher the mean effective pressure, the lower will be the first cost of a steam engine for any given power.

(2) For multiple-expansion unjacketed condensing engines, using saturated steam at about 165 pounds per square inch absolute in the engine cylinder, the best mean effective pressure for normal load is from 40 to 45 pounds per square inch, referred to the L.P. cylinder, and the economy varies but slightly for a considerable range in the mean effective pressure.

(3) For jacketed multiple-expansion condensing engines,

with steam pressure as above, the best mean effective pressure is slightly lower than for unjacketed multiple-expansion condensing engines.

(4) Non-condensing engines have a best mean effective pressure rather higher, and the variation in economy for any given range of mean effective pressure is less than for condensing engines.

(5) For steam pressures higher than 165 pounds per square inch absolute, the best mean effective pressure is higher than from 40 to 45 pounds per square inch, and is probably as high as from 45 to 50 pounds per square inch referred to the L.P. cylinder, for triple or quadruple-expansion engines using saturated steam over 200 pounds per square inch boiler pressure.

(6) Multiple-expansion engines using saturated steam below 165 pounds per square inch absolute have their best mean effective pressure below from 40 to 45 pounds per square inch, and this best mean effective pressure falls more rapidly with fall of steam pressure for the condensing than for the non-condensing engine.

(7) The more economical an engine can be made, the lower is likely to be the best mean effective pressure, though not to any large extent. Hence, large engines may have a rather lower best mean effective pressure than small engines using steam at the same pressure.

(8) Engines using highly superheated steam, so that the steam is superheated during expansion have a best mean effective pressure lower than for engines using saturated steam, with a consequent increase in first cost for any given power. Such engines have a high thermal efficiency, and will maintain the same efficiency over a wide range of power.

(9) The best mean effective pressure is about 35 pounds per square inch for single-cylinder condensing non-jacketed engines, using saturated steam at about 75 pounds per square inch absolute. For other conditions the same general laws hold good as for multiple-expansion engines.

The following table shows somewhat more concisely the desirable mean referred pressure for different conditions:

TABLE I.

.....	Single-cylinder, 75 pounds absolute.	Multiple-expansion, 165 pounds absolute.	Multiple-expansion, 200 pounds absolute.	Multiple-expansion, 250 pounds absolute.
Unjacketed, non-condensi'g	37	42–47	48–53	53–58
condensing	35	40–45	45–50	50–55
Jacketed, condensing	33	38–43	42–47	47–52
Superheated slightly.....	32	36–41	40–45	45–50
highly	30	33–38	37–42	42–47

In a paper upon "Receiver Drop in Multiple-Expansion Engines," "North-East Coast Institute of Engineers and Shipbuilders" Vol. 16, Prof. Weighton has given the results of certain experiments carried out by him. His conclusions are as follows:

(1) For maximum economy of consumption steam must be cut off at a certain point of the stroke in the larger cylinders (I.P. and L.P.) of multiple-expansion engines. For any given cylinder this point depends solely upon the ratio between the capacities of that cylinder and the preceding cylinder (R), and is expressed as follows:

$$\frac{\text{Maximum-economy cut-off}}{\text{Stroke}} = .15 + \frac{1}{R}.$$

This is the principal and most important conclusion deduced from the trials.

(2) It follows from No. 1 that the cut-off in the larger cylinders, once fixed, should never be altered, whatever may be the cut-off in the high-pressure cylinder, or the steam pressure employed. This means that automatic-expansion governors, or linking-up gear, should act upon the high-pressure cylinder only, if maximum economy at all powers is to be preserved.

(3) The cut-off in the larger cylinders affects materially the total horsepower developed by the engines. As regards the low-pressure cylinder of triples, and the second intermediate and low-pressure cylinders of quadruples, maximum power cut-off in these cylinders coincides with the cut-off of maximum economy. As regards the second cylinder of triples and

quadruples, maximum power cut-off is very considerably later than that of maximum economy. In compounds the maximum power cut-off in the low-pressure cylinder is only slightly later than that of maximum economy.

(4) When cylinder ratio (R) is small—say from 2 to 2.5—the cut-off in the larger cylinders may be varied considerably from that corresponding to maximum economy without any appreciable fall in economy. But when (R) is large there is no such permissible deviation without entailing as a consequence a fall in efficiency.

(5) With given efficiency in receiver drop, smallness of cylinder ratio is conducive to smoothness of working, uniformity of turning, durability, handiness in starting and reversing and compactness of design.

(In getting values of (R) include the effect of piston rods and clearance spaces.)

For economy the cut-offs should be $.15 + \frac{1}{R}$. (Weighton.)

For maximum power the cut-offs should be $(.15 + \frac{1}{R})$ 1.4 in I.P. cylinder

For maximum power the cut-offs should be $(.15 + \frac{1}{R})$ in L.P. cylinder.

For smooth running cut-offs should be late.

In the "JOURNAL" for November, 1909, will be found the results of trials upon the U. S. S. *Delaware*, whose engines developed their maximum power with a mean referred pressure of 52.4 pounds, using 8.7 actual expansions. In the "JOURNAL" for August, 1910, on pages 744–6, will be found Table G, giving the results of trials upon the U. S. S. *Birmingham*, whose engines developed their maximum power with a mean referred pressure of 35 pounds, using 11.35 expansions. The results of certain trials upon H. M. S. *Argonaut* are given in the "Trans. of the Inst. of Naval Architects," Vol. 41, 1899.

The results of these trials agree with the conclusions of Mr. Royds and Prof. Weighton, given in the first part of this

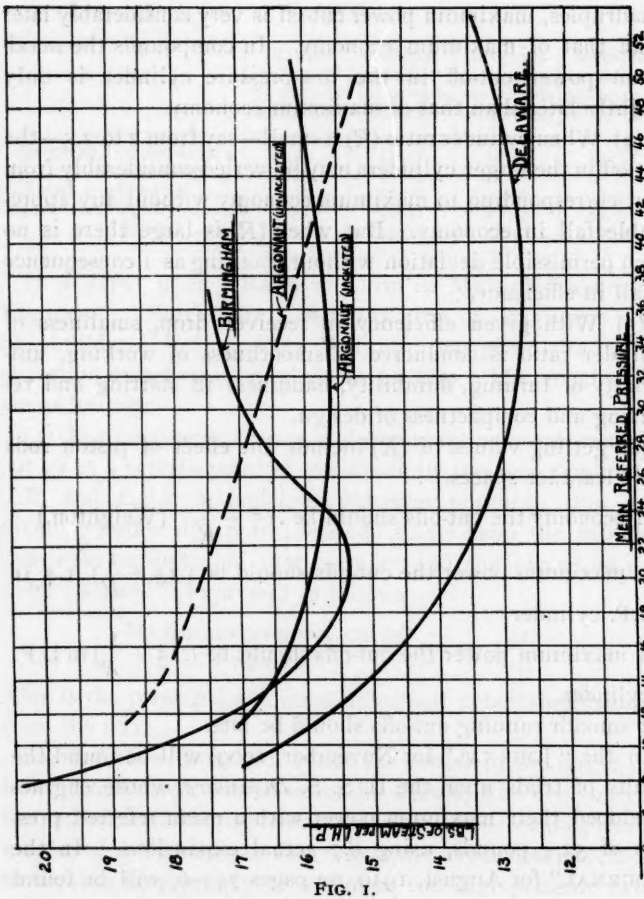

BIRMINGHAM
ARGONAUT (CONDENSING)
ARGONAUT (NON-CONDENSING)
DELAWARE
MEAN REFERRED PRESSURE
LBS. OF STEAM PER I.H.P.
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
20 19 18 17 16 15 14 13 12

FIG. 1.

article. If the *Birmingham's* engines had been designed to develop their maximum power with about eight expansions and a mean referred pressure of about 55 pounds their steam consumption at maximum power would have been reduced fully 20 per cent. The fact that these engines were unjacketed, used saturated steam and had large clearance volumes will account for only a small part of the difference. The steam on the *Delaware* was only slightly superheated, and the in-

crease in economy due to its use could not have been more than 5 per cent., while the jackets were probably detrimental to economy at full power.

In Tables II and III are given certain data concerning these three engines, and from this and other data obtained from the sources mentioned above, the curves in Fig. 1 have been drawn.

TABLE II.

.....	Diameter.	Clearances.	Cyl. vol. ratios.	Econom. cut-offs.	Cut-offs used.	
		per ct.				
Delaware, H.....	38½	16.2	1	...	...	About 55° superheat.
I.....	57	13.4	2.15	.62	.70	Liners jacketed, I.P. and L.P. ends.
L..	76	12.4	7.6	.43	.38	
Argonaut, H	34	25	1	...	...	Liners jacketed.
I.....	55½	20	2.6	.54	.67	
L	64	15	6.65	.54	.46	
Birmingham, H	28½	26.2	1	...	...	No jackets.
I.....	45	21.3	2.5	.55	.75	
L	62	21.1	9.6	.41	.6	

TABLE III.

.....	I.H.P.	Piston speed.	Cut-offs.	Actual expansion R_e.	Initial press. absolute P_i.	$\frac{P_i}{R_e}$	Mean referred pressure.	Vacuum.	Pounds steam per I.H.P.
			H. — I. — L.						
Delaware	14,716	1,025	86—80—62	8.7	263	30.2	52.4	26.3	13.4
Argonaut	9,390	1,020	71—67—46	8.7	245	28.3	47.3	26	15.75
Birmingham..	7,385	1,153	79—75—60	11.35	233	20.5	34.8	27.5	17.4
Delaware	8,784	870	86—70—38	8.7	186	21.4	36.9	26 9	12.7
Argonaut	6,906	930	73—67—46	8.5	189	22.3	38	26.5	16.2
Birmingham..	5,431	1,040	79—75—60	11.35	194	17.1	28.5	27.7	16.8
Delaware	2,049	544	86—70—38	8.7	78.5	9	13.8	27.7	15.1
Argonaut	1,933	610	73—67—46	8.5	77	9.1	16.2	26.4	17.7
Birmingham..	1,565	679	79—75—60	11.35	95.5	8.4	12.6	26	16.9

It will be noticed that the curves for the *Argonaut*, jacketed, and the *Delaware* are similar in character at the higher powers, and, judging from the results of the unjacketed trials on the *Argonaut's* engines, the steam consumption of the *Dela-*

ware's engines would probably be 5 per cent. less at maximum power if the jackets were not in use.

Lieutenant Milner, U. S. N., in an article in the "JOURNAL" for August, 1912, gives a table of results obtained by Chief Engineer Isherwood from trials upon the engines of the *Siesta*. From these results and others Isherwood drew the conclusion that "no economic gain could be obtained by expanding the steam more than four or five times, even in a compound engine using saturated steam of a very high pressure, in jacketed cylinders with pistons working at very high reciprocating speeds."

Certain results calculated from the data taken from Table I of Lieut. Milner's article are given below in Table IV, and these results have been plotted in Fig. 2. It will be noticed that these results agree with the conclusion of Mr. Royds, that higher mean referred pressures are necessary for economy. In every case the use of lower mean referred pressures is accompanied by increased steam consumption. The effect upon the steam consumption of the per cent. of cut-off used in the L.P. cylinder can be seen in the case of trial I, where a steam consumption of 18 pounds per I.H.P. would probably be obtained with a cut-off of .45 instead of 19.2 pounds with a cut-off of .874.

TABLE IV.

Siesta.—Unjacketed cylinders $\frac{10\frac{1}{2} \text{ inches to } 18 \text{ inches.}}{18 \text{ inches}}$

Clearances: H.P. — 9 per cent.; L.P. — 2.5 per cent.
Cut-off in L.P. for max. economy = .5.

.....	A	B	C	D	E	F	G	H	I	J	K	L
I.H.P	66.7	84.9	88.1	13.12	100.9	105.3	92.9	96.8	106.9	141.	113.1	119.2
R.P.M.....	146.5	169.4	170.3	190.2	177.9	178.5	173.3	177.1	176.6	193.1	185.3	184.4
M.R.P	19.8	21 7	22.4	29.9	24 6	25.6	23.2	23.7	26.2	31.7	26.5	28.
P_i (absolute)	110.3	102.9	105.3	105 2	96.5	82.2	80.4	78.3	91.3	66.7	68.6	64 9
M.R.P. ÷ P_i	.18	.21	.213	.285	.255	.311	.288	.303	.286	.478	.386	.43
L.P. cut-off	.263	.237	.465	.208	.237	.452	.846	.857	.874	.298	.871	.87
Lbs. steam per I.H.P.	17.92	18.87	17.91	16.78	18.53	18.02	20.61	20.59	19 22	20.04	24.83	23.81

The best result in these tests was obtained with a mean referred pressure of about 30 pounds, and a still better result would probably have been obtained if the mean referred pressure had been 35 pounds or more.

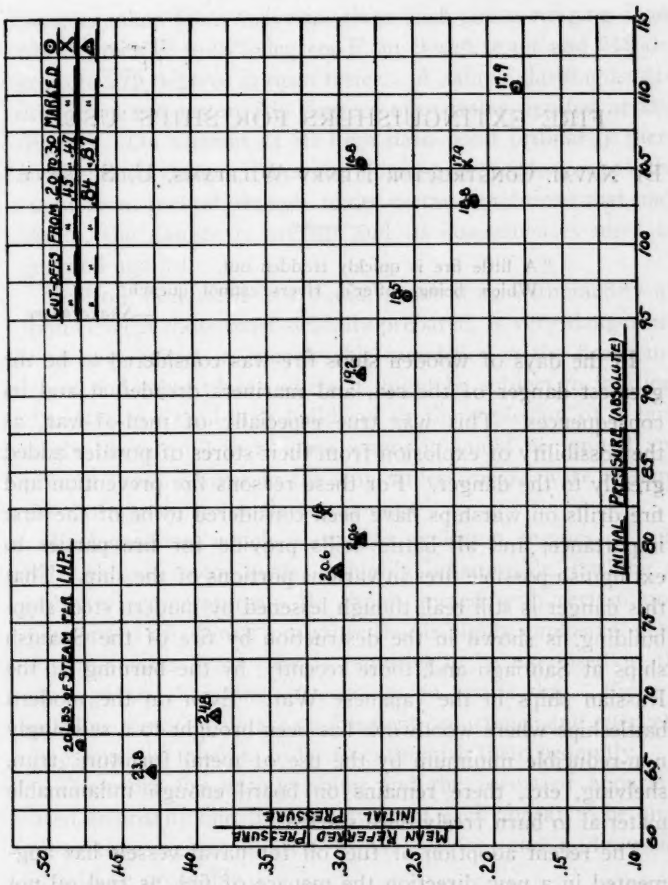


FIG. 2.

In the case of the *Birmingham* and *Delaware* the results would probably have been still more favorable to the *Delaware* if the steam consumption were referred to the shaft horse-power. The results as plotted in Fig. 1 are not reduced to a common back pressure, but the relative positions of the curves would not be changed by so doing.

FIRE EXTINGUISHERS FOR SHIPS' USE.

By Naval Constructor Henry Williams, U. S. Navy.*

"A little fire is quickly trodden out,
Which, being suffer'd, rivers cannot quench."
—*Shakespeare.*

In the days of wooden ships fire was considered to be the greatest danger of the sea, and mariners dreaded it and its consequences. This was true especially of men-of-war, as the possibility of explosion from their stores of powder added greatly to the danger. For these reasons fire prevention and fire drills on warships have been considered to be of the first importance, and all battle drills provide for fire parties to extinguish possible fires in various portions of the ship. That this danger is still real, though lessened by modern steel shipbuilding, is shown in the destruction by fire of the Spanish ships at Santiago and, more recently, by the burning of the Russian ships in the Japanese War. Even on the modern battleships where woodwork has been brought to a seemingly non-reducible minimum by the use of metal furniture, trim, shelving, etc., there remains on board enough inflammable material to burn freely once started.

The recent adoption of fuel oil for naval vessels has augmented in a new direction the menace of fire, as fuel oil not only is highly inflammable, but its vapors, when mixed with certain proportions of air, form an explosive mixture.

The fuel oil purchased for naval vessels is crude petroleum, from which the lighter fractions, such as benzene and kerosene, have been removed by distillation. The flash point is required to be not less than 200 degrees F. in a closed tester.

* The author acknowledges assistance received in preparation of this paper from Mr. R. P. Walsh, Laboratorian, and Mr. J. P. Millwood, Chemist, Navy Yard, New York.

Samples taken from deliveries show flash points ranging from 214 degrees F. to 275 degrees F. in closed tester and 242 degrees to 279 degrees in open tester. A sample flashing at 214 degrees closed tester, 256 degrees open tester, ignited at 294 degrees. On account of its high flash point ordinarily there is not much danger from the burning or explosion of the vapor from fuel oil, though, under certain conditions that may obtain, the danger is present and its consequences must be guarded against.

Fuel oil, because it is a liquid, penetrating with facility all joints except those most skilfully prepared, is very dangerous, as it may collect in considerable quantities in the firerooms, bilges and other places where it might be subject to ignition. Accident to an oil-tank bulkhead or the explosion of a tank might liberate oil in a space where it would be ignited and present grave danger to the ship, unless means were at hand for extinguishing the flames at once.

Fuel gasoline, which is used in explosion engines of submarines and motor boats, is highly inflammable, flashing at ordinary temperatures. Its vapor, mixed with certain proportions of air, forms a mixture that is highly explosive. Due to these facts great care is required to be exercised in the stowage and handling of gasoline on board ship. Fires in gasoline motor boats are of frequent occurrence and energetic steps must be taken in order to extinguish them promptly.

Therefore fire extinguishing and the forms of apparatus used ordinarily and the limitations of each appear to be questions that present interest to the service, and a discussion should be profitable.

Combustion is the process of the rapid combination of a substance with oxygen—usually that contained in the air. In order that combustion may take place two conditions must obtain: the substance must be brought to and maintained at its temperature of ignition and there must be a sufficient supply of oxygen to feed the combustion. After fire has been started, the temperature necessary to continue the action generally is maintained by the burning of the substance. In order to extinguish fire, either the temperature of the burning body

must be lowered below the ignition point or the supply of oxygen must be cut off. This latter is the underlying principle under which practically all systems of fire extinguishing function, as they involve the direct or indirect application to a burning surface of a substance which acts to exclude air and so stops combustion. There are many different methods of accomplishing this end.

WATER.

By far the most common fire-extinguishing agent is water. Its action probably is two-fold; due to its high latent heat of vaporization its evaporation reduces the temperature of the burning substance, or, in the form of water or steam it covers the burning surface excluding air. Many firemen, however, believe that very fierce fires are increased by the application of water. This could occur through dissociation of the water into its component elements of hydrogen and oxygen, which phenomenon takes place at a temperature of about 1,800 degrees F., or, in the presence of certain substances, at a much lower temperature.

Water, such as sea-water, containing salt, or any other similar solid, in solution, is a more effective extinguisher than fresh water, as the solid, deposited by the evaporating water on a burning surface, retards the combustion and renders the fuel less easily inflamed. The various systems of fire-proofing wood and textiles depend on filling their pores with solids, and as long as the pores remain filled inflammability is reduced to a marked degree.

It is a common practice to add to the water in fire barrels and buckets such soluble solids as common salt and calcium chloride. These not only increase the fire-extinguishing properties of the water, but serve the important function of reducing its freezing point, so that in cold weather it does not freeze. Calcium chloride probably is most generally used for this purpose. Use is made of the above principle in hand grenades—these will be discussed later; and in a commercial fire extinguisher, in which the fire-extinguishing liquid, which consists usually of a solution of calcium chloride in water, is

ejected through the nozzle by pressure from compressed carbon dioxide gas which is contained in a metal cylinder having a soft cap readily punctured by operating the handle.

Water, however, cannot be used as a universal fire extinguisher as it has no effect on certain burning substances, notably petroleum oils and their derivatives. It does not mix with these latter and, as it is heavier, the water goes to the bottom, and the oil floating on its surface burns freely despite the water. Therefore the use on naval vessels of fuel oil and fuel gasoline has rendered necessary the adoption of fire-extinguishing arrangements other than those depending for their effectiveness on water.

SAND.

Sand is one of the most useful fire extinguishers for fires in such locations as will permit its being applied directly to the burning surface. It acts as a blanket, cutting off the oxygen from the burning surface on which it rests. It is very effective on oil and gasoline fires, and is used generally for fires in electrical apparatus where water would cause a short circuit and increase the fire. Sand, however, must be applied directly to the burning surfaces, as it does not flow; therefore for fires in inaccessible locations it is ineffective.

HAND GRENADES.

These consist of bottles filled with a fire-extinguishing liquid. They have been issued for many years to naval vessels, 300 being provided for in the allowance books of recent battleships. The specifications under which they are purchased for the Navy require one-quart bottles, approximately spherical in shape with corrugated sides, to permit ready fracture in use. No particular ingredients are specified, though the liquid is required to resist freezing at 10 degrees F. below zero, and not to cause explosion of the bottle at 150 degrees F. An acceptance test of samples taken from each delivery, in extinguishing fires of certain specified dimensions and fuel is required.

The contents of the hand grenades generally delivered now under naval contracts consist of a solution of ammonium phosphate in water, though formerly calcium chloride was used. As previously pointed out, a solid in solution in water adds considerably to its fire-extinguishing properties. The ammonium phosphate has the additional advantage, theoretically at least, of disintegrating when heated, giving off ammonia gas, which does not support combustion and so aids in extinguishing a fire.

The hand grenades, which are expected to break when thrown into a fire and so apply their contents to the flames, are not so efficient as other forms of fire extinguishers. This is due to the difficulty, even in favorable locations, of applying them to the fire at the best point. When fires are overhead or in inaccessible places they can not be expected to be of any use. There are many more modern types of extinguishers, as will be seen, that project the liquid to a considerable distance, greater than the hand grenade can be thrown, and which even do not depend entirely on direct application to the flames of the extinguishing agent.

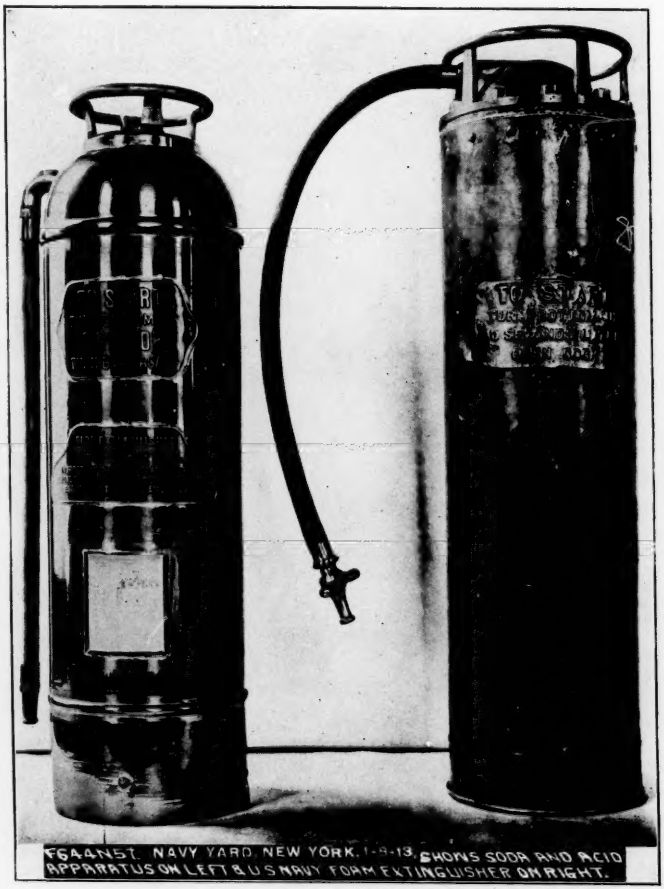
DRY-POWDER EXTINGUISHERS.

These had a vogue for a number of years, and consist generally of dry powder enclosed in a metal cylinder of small diameter. One end of the cylinder is closed by a cap which is removed by pulling the extinguisher from its hook. The dry powder consists almost invariably of ordinary bicarbonate of soda, which when heated even to the temperature of boiling water gives off carbon dioxide gas.

$$2NaHCO_3 = Na_2CO_3 + H_2O + CO_2.$$

As is well known, this gas does not support combustion and, being heavier than air, settles over a burning surface, cutting off the oxygen and extinguishing the flame.

In some forms of the dry-powder extinguishers lamp black and sodium nitrate are added to the powder. These form a



COMMERCIAL SODA-AND-ACID 3-GALLON EXTINGUISHER ON LEFT.
NAVY DEPARTMENT PORTABLE FOAM EXTINGUISHER ON RIGHT.

sort of gunpowder intended to explode when a fire starts, and so to scatter the powder over the flame, at the same time starting the decomposition of the soda.

These dry-powder extinguishers leave much to be desired, as the amount of carbon dioxide gas given off is small and the difficulty of applying it to the burning surface is great. It is said that the inefficiency of this type of extinguisher and the time lost in attempting to use them were responsible for the Iroquois Theater fire in Chicago, some years ago.

CHEMICAL FIRE EXTINGUISHERS.

One of the most efficient and popular types is the soda and acid, or chemical, fire extinguisher. This consists, in principle, of a container with a concentrated solution of sodium carbonate or bicarbonate in suspension and solution and a bottle of acid, usually sulphuric. When the container is inverted the acid runs out of the bottle and acts on the soda mixture to form carbon dioxide gas.

$$Na_2CO_3 + H_2SO_4 = Na_2SO_4 + H_2O + CO_2.$$
$$\text{or } 2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2H_2O + 2CO_2.$$

The pressure generated expels the mixture through a hose and nozzle, and it can be directed readily against the fire. The projected liquid, which contains in solution the solid and in mixture some of the carbon dioxide gas, is an efficient fire-extinguishing agent.

Extinguishers of this type are purchased for use in navy yards in the three-gallon size. The specifications covering them are in great detail and specify the characteristics and the tests to which deliveries are to be subjected. The time of discharge is required to be as nearly as possible sixty seconds.

Due to evaporation and deterioration of the soda solution and its effect on the container and orifice, it is necessary to test and recharge such extinguishers annually, and it is desirable to inspect them monthly. There is some danger connected with the use of these extinguishers, as, if the orifice becomes stopped, an explosion may result from an attempt to

use the appliance. There is always the danger of their failing to operate. In such an event, or in case the solution has deteriorated, serious damage might result from a fire unchecked through failure of apparatus depended upon.

Another disadvantage connected with the soda-and-acid extinguisher is the fact that the projected liquid contains soda and some acid, and consequently is apt to cause damage to machinery or furnishings. Obviously, this extinguisher is not effective for oil or gasoline fires, as the amount of carbon dioxide gas is insufficient to have any marked effect and the liquid has no effect at all.

HEAVY-GAS EXTINGUISHERS.

On shipboard general use is made of fire-extinguishing systems which depend upon the introduction into the burning compartment of a heavy gas which does not support combustion and which displaces the air and so extinguishes the fire. Steam is used generally on shipboard for this purpose, as it is available readily and usually is fairly efficient. There are many fires, however, which, due to their intensity or for other reasons, are not affected appreciably by steam. Carbon dioxide gas, also, has been used for the purpose successfully, and one such system has been adopted on many merchant ships and has proved itself to be surprisingly efficacious in serious cargo fires.

Such a system, also, has been adopted on several recent oil-burning naval vessels for the inaccessible storerooms located between the engine rooms and firerooms and through which oil pipes pass. Due to the possibility of leakage or damage to the oil pipes and to the fact of the storerooms being located under magazines, it is of the utmost importance to be able to cope promptly with any fire that might be started. The carbon dioxide gas is stored at about 800 pounds pressure in cylinders. In order to ensure its being expanded without the pipes becoming clogged by solidified gas, a steam-heating coil is fitted. The carbon dioxide gas when liberated passes through the heater, thence to a manifold from which it may

be directed, through appropriate piping, to the compartment concerned.

The cylinders once exhausted must be recharged, and the inconvenience of this, as well as the danger involved through the storage of tanks containing high-pressure gas, and in the liberation of carbon dioxide gas, open this system to serious objection.

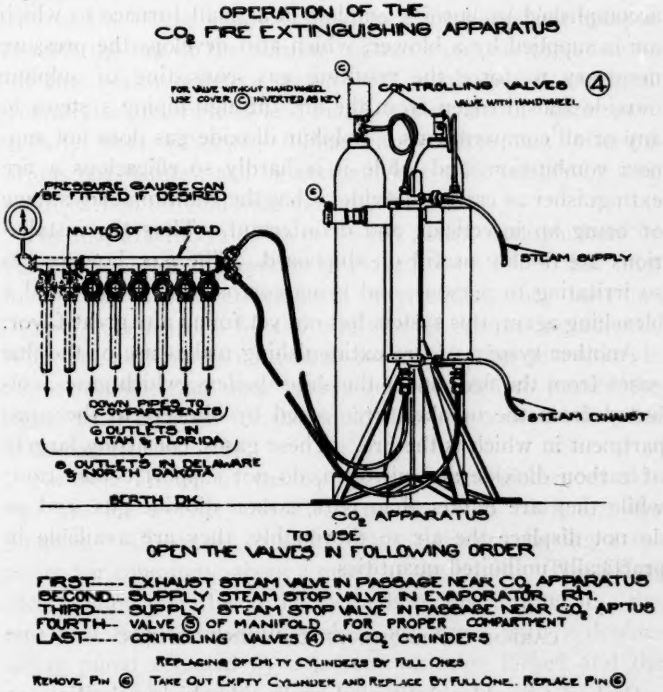

OPERATION OF THE
CO2 FIRE EXTINGUISHING APPARATUS
FOR VALVE WITHOUT HANDWHEEL USE COVER (C) INVERTED AS KEY
CONTROLLING VALVES (4)
VALVE WITH HANDWHEEL
PRESSURE GAUGE CAN BE FITTED IF DESIRED
VALVE (5) OF MANIFOLD
STEAM SUPPLY
STEAM EXHAUST
DOWN PIPES TO COMPARTMENTS
6 OUTLETS IN UTAH & FLORIDA
6 OUTLETS IN DELAWARE & NORTH DAKOTA
BERTH DK.
CO2 APPARATUS
TO USE
OPEN THE VALVES IN FOLLOWING ORDER
FIRST---- EXHAUST STEAM VALVE IN PASSAGE NEAR CO2 APPARATUS
SECOND-- SUPPLY STEAM STOP VALVE IN EVAPORATOR RM.
THIRD---- SUPPLY STEAM STOP VALVE IN PASSAGE NEAR CO2 APTUS
FOURTH-- VALVE (5) OF MANIFOLD FOR PROPER COMPARTMENT
LAST----- CONTROLING VALVES (4) ON CO2 CYLINDERS
REPLACING OF EMPTY CYLINDERS BY FULL ONES
REMOVE PIN (6) TAKE OUT EXPTY CYLINDER AND REPLACE BY FULL ONE. REPLACE PIN (6)

DIAGRAM SHOWING ARRANGEMENT AND INSTRUCTIONS FOR OPERATING CO_2 FIRE-EXTINGUISHING APPARATUS INSTALLED RECENTLY ON SOME BATTLESHIPS.

As is well known carbon dioxide gas does not support life and, due to its lack of odor, gives no warning of its presence. Persons entering a compartment where it has been liberated, either intentionally or accidentally, incur danger of losing their lives unless removed at once. Ten per cent. of carbon

dioxide gas mixed with air has been known to prove fatal, and continued breathing of two per cent. is dangerous. For this reason it becomes desirable to develop systems of fire extinguishing for ship use which do not depend upon this deadly gas for their efficacy.

Recently installation has been made on several merchant ships of apparatus generating sulphur dioxide gas. This is accomplished by burning sulphur in a small furnace to which air is supplied by a blower, which also develops the pressure necessary to force the resulting gas, consisting of sulphur dioxide and nitrogen from the air, through piping systems to any or all compartments. Sulphur dioxide gas does not support combustion, and while it is hardly so efficacious a fire extinguisher as carbon dioxide, it has the additional advantage of being an insecticide and disinfectant. Thus the installations are doubly useful on shipboard. The gas, however, is so irritating to persons, and being corrosive to metals, and a bleaching agent, this system has not yet found any great favor.

Another system of fire extinguishing makes use of the flue gases from the fires under the ships' boilers, which gases, collected from the uptakes, are forced by blowers to the compartment in which is the fire. These gases, consisting largely of carbon dioxide and nitrogen, do not support combustion; while they are lighter than pure carbon dioxide gas, and so do not displace the air so thoroughly, they are available in practically unlimited quantities.

CARBON TETRACHLORIDE EXTINGUISHERS.

Carbon tetrachloride is a clear liquid which volatilizes at 77 degrees C.; neither it nor its vapor being combustible, nor do they support combustion. Carbon tetrachloride has a strong, rather pungent and unpleasant odor, though its vapor is not poisonous if inhaled. It costs about $1.75 per gallon and can be obtained readily commercially. It is non-corrosive to metals and does not damage textiles. Indeed, it is used successfully as a cleaning fluid and it is sold as such under a

proprietary name. It is a non-conductor of electricity, and can be used on electric arcs and fires in electrical apparatus where heretofore sand has been the only substance used. Carbon tetrachloride has all the properties necessary to form an admirable fire-extinguishing agent, and several systems that have achieved great popularity recently depend on it for their efficacy. It is especially effective for gasoline and fuel-oil fires, as the heavy vapor formed by its evaporation quickly blankets the top of the burning oil and stops the combustion. For this reason patent extinguishers employing it are used generally in automobiles and motor boats. In the latter particularly, fires, otherwise difficult to combat and offering serious possibilities, can be extinguished quite readily by the use of carbon tetrachloride extinguishers.

The manufacturers of some of the patent extinguishers in which a liquid of this type is employed claim either that they do not use carbon tetrachloride or else that they have increased its efficiency by the addition of secret ingredients. While the author has no definite information on this point, it seems probable that these claims are advanced to justify the higher price charged for the liquid than the commercial price of carbon tetrachloride.

The best known of the commercial extinguishers of this type are the Pyrene, the Electrene, the Red Devil and the Simplex. All consist of small brass cylinders having a capacity for containing about a quart of the liquid. The differences among them lie in the methods of discharging it. Pyrene and Red Devil extinguishers are fitted with a double-acting pump actuated by a piston, which is locked and the nozzle closed by turning it one half turn.

The Electrene extinguishers have a pump for compressing air. The apparatus, after being charged, when needed for use, is operated by opening a pet cock and the liquid is ejected by the air pressure. The Simplex extinguishers are fitted with a small steel capsule of liquid carbon dioxide gas, similar to those used for charging the "sparklet" syphons. When the extinguisher is required for use the steel capsule is punc-

tured and the gas, expanding, expels the extinguishing liquid through a nozzle.

Extinguishers using carbon tetrachloride enjoy many advantages over those depending on carbon dioxide. It volatilizes at a comparatively high temperature, and consequently it may be present in compartments without involving any particular danger to persons, and its odor is so pungent that con-

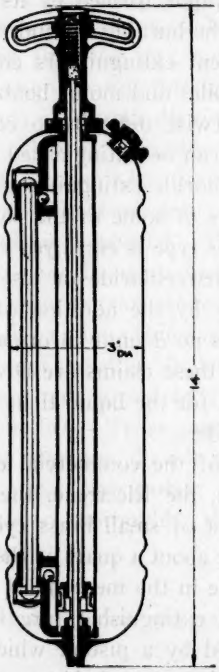


DIAGRAM SHOWING ARRANGEMENT OF DOUBLE-ACTING PUMP USED FOR EJECTING THE LIQUID FROM THE PYRENE TETRACHLORIDE-TYPE EXTINGUISHER.

tinued breathing of the vapor would hardly be possible. The knowledge of its qualities is comparatively new, and formerly where it is used now chloroform was used to some extent for fire extinguishing, though its vapor is combustible under certain conditions. The two substances are similar, the formula

for carbon tetrachloride being CCl_4, while chloroform is $CHCl_3$.

The Navy Department has issued specifications covering extinguishers of this type for use on motor boats, torpedo craft and submarines. They require containers with a capacity of from one to one-and-a-half quarts, and a system capable of projecting the liquid not less than twenty feet.

Carbon tetrachloride also offers possibilities as a substitute for the heavy-gas fire-extinguishing systems, already discussed, using carbon dioxide or sulphur dioxide. An appara-

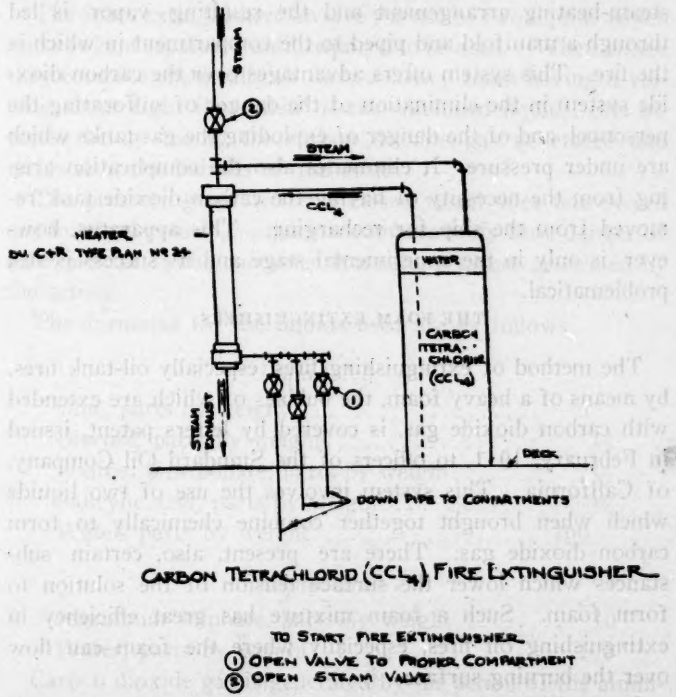


DIAGRAM SHOWING ARRANGEMENT OF PROPOSED CARBON TETRACHLORIDE VAPOR FIRE EXTINGUISHER. WHEN THE STEAM VALVE IS OPENED THE TETRACHLORIDE IN THE TANK IS FORCED OUT AND IS VAPORIZED IN THE HEATER. THE RESULTING VAPOR IS CONDUCTED TO THE COMPARTMENT AFFECTED, AND, DISPLACING THE AIR, EXTINGUISHES THE FLAME.

tus has been designed at the New York Navy Yard intended for use in place of the CO_2 extinguishers, several of which have been installed on ships for the inaccessible storerooms through which oil piping passes and which are located under magazines. The proposed apparatus consists of a tank containing carbon tetrachloride and a small quantity of water, which floats on top, and is intended to protect the tetrachloride from the steam. The tetrachloride is forced out of the tank through a pipe dipping to the bottom, by steam pressure admitted at the top. Thence the tetrachloride passes through a steam-heating arrangement and the resulting vapor is led through a manifold and piped to the compartment in which is the fire. This system offers advantages over the carbon dioxide system in the elimination of the danger of suffocating the personnel, and of the danger of exploding the gas tanks which are under pressure. It eliminates also the complication arising from the necessity of having the carbon dioxide tank removed from the ship for recharging. This apparatus, however, is only in the experimental stage and its success is still problematical.

THE FOAM EXTINGUISHERS.

The method of extinguishing fires, especially oil-tank fires, by means of a heavy foam, the bubbles of which are extended with carbon dioxide gas, is covered by letters patent, issued in February, 1911, to officers of the Standard Oil Company, of California. This system involves the use of two liquids which when brought together combine chemically to form carbon dioxide gas. There are present, also, certain substances which lower the surface tension of the solution to form foam. Such a foam mixture has great efficiency in extinguishing oil fires, especially where the foam can flow over the burning surface.

Recognition of the possibilities of serious fires on shipboard arising from the presence of fuel oil led the Bureau of Construction and Repair, in 1910, to appoint a board to consider the general subject of suitable fire-extinguishing appliances to meet the new conditions. This board recom-

mended the adoption of the foam system for all oil-burning ships, and the preparation of designs for suitable apparatus was undertaken. A demonstration of the efficacy of the foam mixture was made for the board at the Bayonne, N. J., plant of the Standard Oil Company. A tank 16 feet by 4 feet was filled to a depth of five inches with naphtha which was ignited by an electric spark, and the flame, which arose to a height of twenty feet, was extinguished in a few minutes by the foam mixture applied to the surface through a stationary pipe.

The foam extinguishers involve the use of two liquids which must be kept separated until required to be used. When mixed they combine chemically to form a heavy foam having a volume about eight times that of the combined liquids, this increase being due to the carbon dioxide gas generated and inclosed in the bubbles of the foam.

The pressure generated in a closed vessel does not exceed one hundred pounds, so there is comparatively little danger of an explosion of the container from the pressure generated by the action.

The formulas for the liquids used are as follows:

Liquid No. 1.

Glue, parts by weight	1
Glucose, parts by weight	½
Sodium bicarbonate, parts by weight	7½
Salicylic acid, parts by weight	¼
Water, parts by weight	100

Liquid No. 2.

Aluminum sulphate, parts by weight	10
Water, parts by weight	100

Carbon dioxide gas is generated by the action of the aluminum sulphate on the sodium bicarbonate.

$$Al_2(SO_4)_3 + 6NaHCO_3 = 3Na_2SO_4 + 2Al(OH)_3 + 6CO_2.$$

The glue and glucose render the liquid viscous and thus foamy. The salicylic acid is added as a preservative for the

glucose, which latter also acts as a stabilizer to prevent the too sudden precipitation of the aluminum hydroxide. At first one-half part, by weight, of sulphuric acid was used in liquid No. 2, with the idea that it aided in starting the action and that it would act, also, as a stabilizer. Its use proved objectionable in adding greatly to the corrosive effect of the liquid on the container, and, experiments having shown that apparently it could be omitted without impairing the efficiency, it has been decided to leave it out tentatively.

As noted, the volume of the foam liquid is about eight times that of the combined liquids. It retains its foamy characteristic for some time, and is sufficiently fluid to flow readily over an oil surface on which it is liberated, covering it entirely if a large enough quantity is supplied. At the same time it is sufficiently viscous and tenacious to stick to any surface against which projected, so that it is effective against fires other than those on surfaces of liquids.

The success of the foam system of fire extinguishers on shipboard is somewhat problematical, due largely to the possibility of deterioration of the solutions in the extinguisher. This may occur by loss through evaporation or deterioration of the ingredients, and service experience only will develop the possibilities. Also, the corrosive effect of the solutions on containers may prove to be serious. Frequent inspection and test of the apparatus and ingredients is imperative if there is to be any assurance that the extinguisher will operate when needed in an emergency.

Another consideration that may affect the use of the foam extinguishers on shipboard is the fact of the liberation by the foam of carbon dioxide gas which will present danger to the personnel unless precautions are taken to remove it.

Two general types of apparatus using this principle have been developed at the New York Navy Yard for installation on oil-burning ships: one, the most important, is small enough to be readily transported; the other is much larger and is installed permanently in the fireroom, connection being arranged

for a fire hose with which to deliver the foam at the desired point.

The type of portable extinguishers as now supplied consists of a cylindrical tank of 24-ounce sheet copper, 24 inches high and 7 inches in diameter. This is fitted with a divisional plate so that the liquids may be kept separate, but are mixed by inverting the tank. A mixing chamber is arranged in the

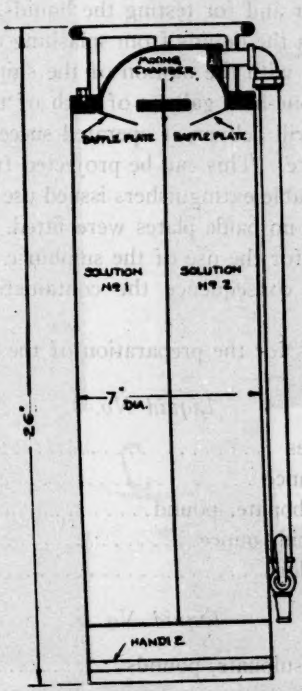


DIAGRAM SHOWING ARRANGEMENT OF PORTABLE FOAM FIRE EXTINGUISHER.

top and a hose with a nozzle and cock are connected to it. An instruction plate is fitted reading as follows: "To start turn bottom up. 10 seconds later open cock." The cock is kept closed to allow mixing to start properly and to generate sufficient pressure to expel the liquid. This cock is one of the

weak features of the apparatus, as the handle may become stuck. Being on the end of the hose, however, it can be removed readily by cutting the hose, and the pressure generated by the liquids should not be sufficient to cause an explosion even with it closed.

The tank is fitted with a cast-composition head bolted on, so there will be no difficulty in removing it for examination of the container and for testing the liquids. Baffle plates are fitted to prevent the liquids from splashing over the top of the divisional plate with the motion of the ship. The containers hold one and one-half gallons of each of the liquids, so that the apparatus will deliver, if operated successfully, 24 gallons of foam mixture. This can be projected from 20 to 30 feet. In the first portable extinguishers issued use was made of steel containers, and no baffle plates were fitted. The instructions provided, also, for the use of the sulphuric acid in one of the liquids. As a consequence the containers corroded away rapidly.

The formulas for the preparation of the liquids are as follows:

Liquid No. 1.

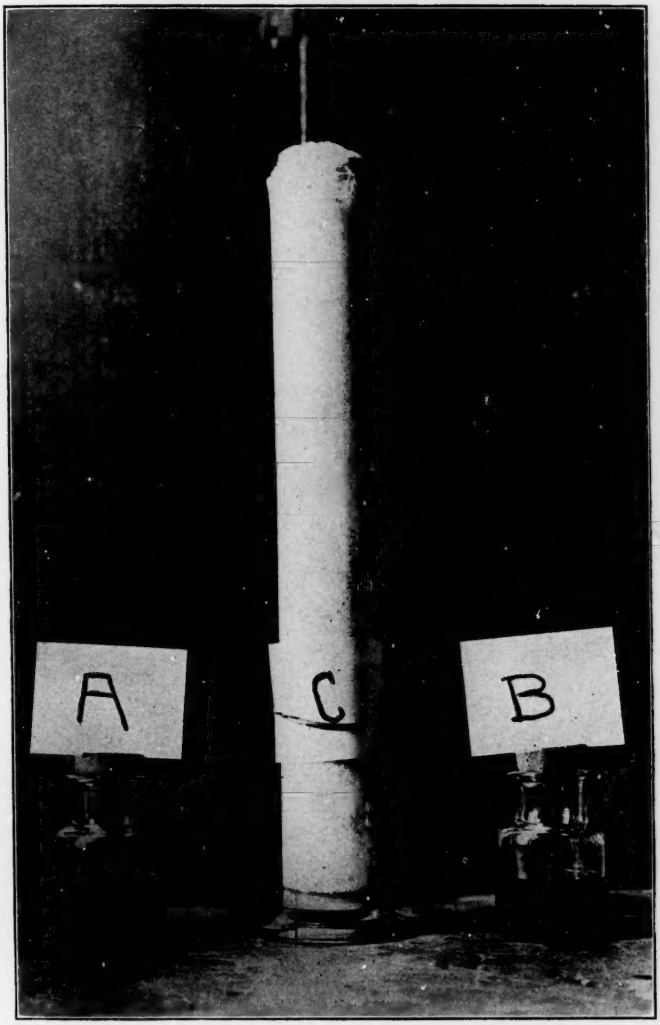
Glue, ounces	2
Glucose, ounce	1
Soda bicarbonate, pound	1
Salicylic acid, ounce	½
Water, gallons	1½

Liquid No. 2.

Aluminum sulphate, pounds	1¼
Water, gallons	1½

The instructions for mixing are as follows:

Liquid No. 1. (*a*) Dissolve glue in one quart of hot water. (*b*) Dissolve salicylic acid in one quart of hot water. (*c*) Dissolve glucose in one pint of hot water. (*d*) Dissolve the sodium bicarbonate in about two quarts of cold water. Then add in the other ingredients and enough water to make one

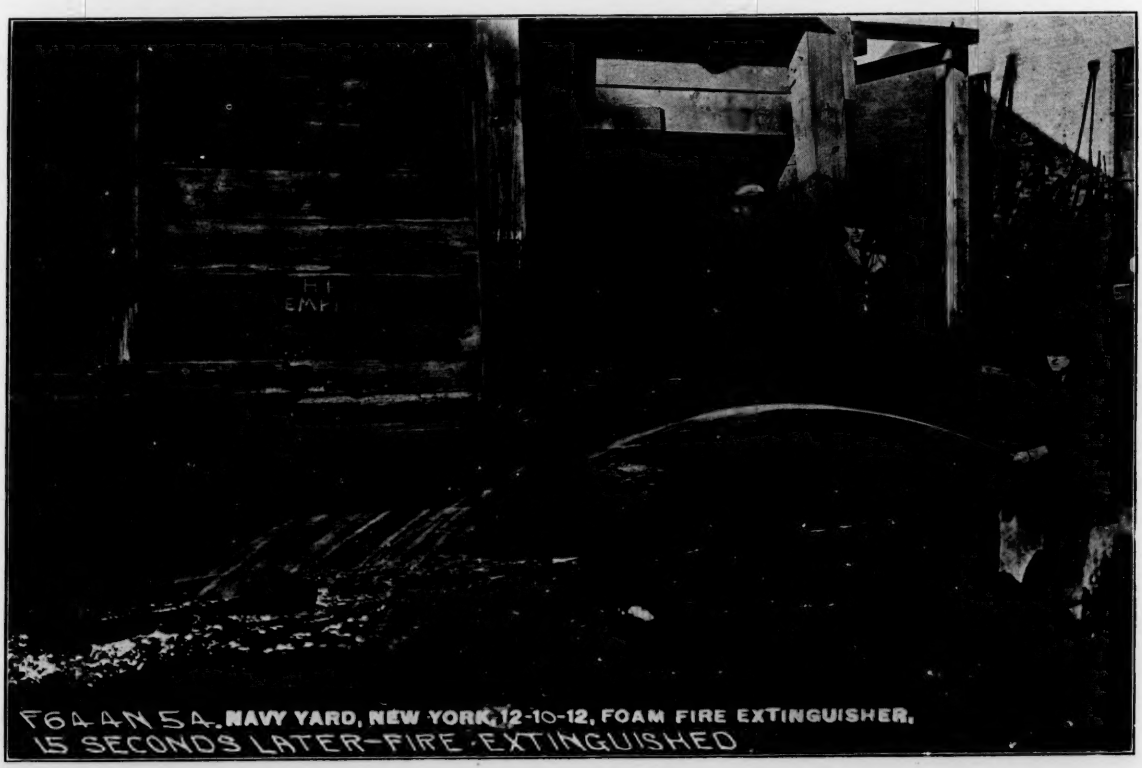


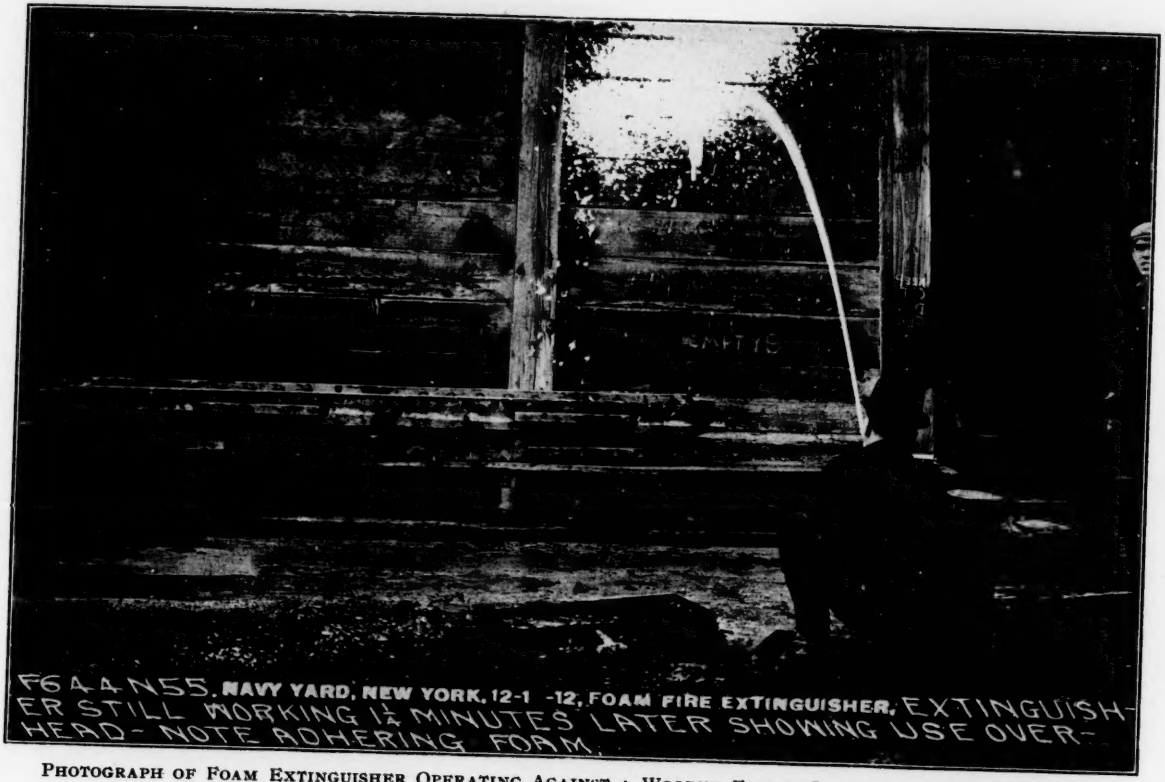
F644 N56, Navy Yard, New York, 12–11–12. Foam Fire Extinguisher. Liquids used, "A" and "B". Resultant volume, "C".

PHOTOGRAPH SHOWING RELATIVE VOLUME OF THE COMPONENT LIQUIDS AND THE RESULTING FOAM.

Two Photographs Showing the Portable Foam Extinguisher Operating Against a Gasoline Fire. The Fire was Extinguished in 15 Seconds.

WAS EXTINGUISHED IN 15 SECONDS.




F644N55. NAVY YARD, NEW YORK, 12-1 -12, FOAM FIRE EXTINGUISHER, EXTINGUISHER STILL WORKING 1¼ MINUTES LATER SHOWING USE OVERHEAD - NOTE ADHERING FOAM.

PHOTOGRAPH OF FOAM EXTINGUISHER OPERATING AGAINST A WOODEN FENCE, SHOWING THE ADHESIVENESS OF THE FOAM.

and one-half gallons of solution. Especial care must be taken that cold water is used for the sodium bicarbonate, as hot water disintegrates it.

Liquid No. 2. (*a*) Dissolve the aluminum sulphate in about one gallon of hot water with constant stirring, and then add enough cold water to make one and a-half gallons of the solution.

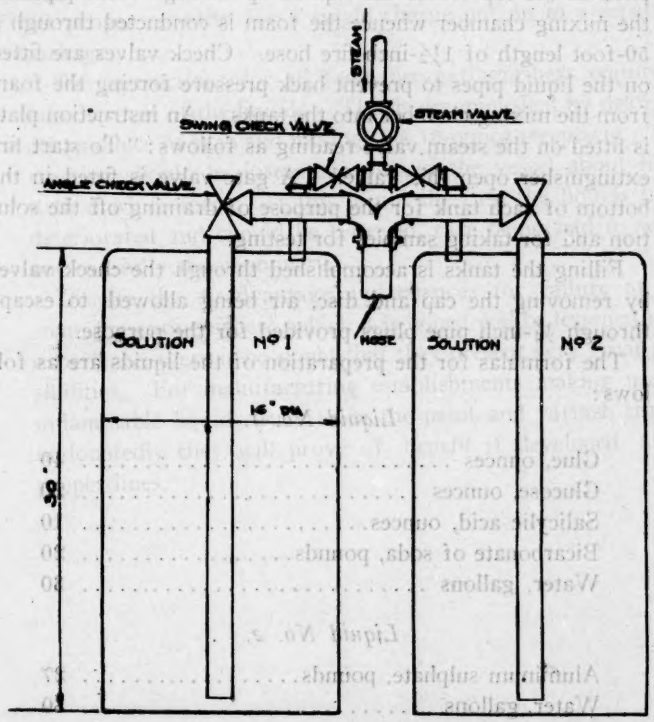


DIAGRAM SHOWING ARRANGEMENT OF PERMANENT FOAM FIRE EXTINGUISHER INSTALLED IN FIREROOMS OF OIL-BURNING DESTROYER.

Care must be taken always to put the liquids in the same side of the container, unless it has been cleaned thoroughly. Also care should be taken not to mix the liquids except for testing purposes or in actual use.

The larger foam fire-extinguishing apparatus, one of which is installed permanently in each fireroom of oil-burning destroyers, has two cylindrical tanks 30 inches high and 16 inches in diameter, each having a capacity for containing 30 gallons of the liquid. Two pipes connecting to a mixing chamber dip to the bottoms of the tanks. Steam pressure applied at the top forces the liquids up through these pipes to the mixing chamber whence the foam is conducted through a 50-foot length of 1½-inch fire hose. Check valves are fitted on the liquid pipes to prevent back pressure forcing the foam from the mixing chamber into the tanks. An instruction plate is fitted on the steam valve reading as follows: "To start fire extinguisher open this valve." A gate valve is fitted in the bottom of each tank for the purpose of draining off the solution and for taking samples for testing.

Filling the tanks is accomplished through the check valves by removing the cap and disc, air being allowed to escape through ¾-inch pipe plugs provided for the purpose.

The formulas for the preparation of the liquids are as follows:

Liquid No. 1.

Glue, ounces	40
Glucose, ounces	20
Salicylic acid, ounces	10
Bicarbonate of soda, pounds	20
Water, gallons	30

Liquid No. 2.

Aluminum sulphate, pounds	27
Water, gallons	30

The instructions for mixing are as follows:

Liquid No. 1. (*a*) Dissolve glue in one gallon of hot water and add one or two more gallons of hot water to solution. (*b*) Dissolve salicylic acid in one gallon of hot water. (*c*) Dissolve glucose in one gallon of hot water. (*d*) Dissolve sodium bicarbonate in 20 gallons of cold water, add in the

other solutions and add enough cold water to make up 30 gallons. Especial care to be taken that cold water is used for the sodium bicarbonate, as heat disintegrates it.

Liquid No. 2. (*a*) Dissolve the aluminum sulphate in 25 gallons of cold water with constant stirring, and add enough more water to bring solution to 30 gallons.

The various solid ingredients are purchased each having the proper quantity for a single charge put up in a separate package.

The instructions for all foam fire extinguishers require a monthly test of the liquids. This is accomplished by drawing off an ounce of each and mixing in a 16-ounce receptacle. The reaction should be instantaneous and the vessel about filled with a white foam. If this is not the case the liquids have deteriorated and should be renewed, care being had to wash out carefully the containers.

Despite the disadvantage and chances for failure of the foam fire extinguishers, which it is hoped will be lessened with experience, there is no doubt that they present very great possibilities. For manufacturing establishments making use of inflammable liquids, such as in the paint and varnish trades, undoubtedly they will prove of benefit if developed along proper lines.

THE LILLIE QUADRUPLE EVAPORATOR, U. S. S. *DIXIE*.

DESCRIPTION AND TEST.

The evaporating plant was "The Lillie Quadruple-Effect Sea-Water Distilling Plant," designed and patented by S. Morris Lillie, of Philadelphia, Pa., and installed by the Sugar Apparatus Manufacturing Company, of Philadelphia, Pa.

It is peculiar to such a degree in its mode of operation and in other respects as to make it radically different from anything that had been used for the purpose in the Navy. Besides minor ones, there are two very salient differences—(a) the evaporation from the sea water is from films caused by a mechanical showering of the sea water over the evaporating tubes; (b) the movement of the vapors or heat through the apparatus is periodically reversed.

The former greatly promotes the efficiency of the evaporating surface, and the latter, by a frequent changing of the temperatures throughout the effects, prevents incrustations to such a degree that the apparatus may be run for long periods without a material falling off in capacity.

The rated capacity of the quadruple effect is 25,000 gallons of distilled water per 24 hours.

DESCRIPTION OF THE PLANT.

As shown by the plates, the Quadruple Effect on the U. S. S. *Dixie* consists of four effects, a surface condenser, a combined air and distillate pump, and an engine-driven direct-connected centrifugal cold-water circulating pump. The effects are respectively lettered A, B, C and D in the plates, of which Plate I is a front elevation of the quadruple effect; Plate II,

a plan; and Plate III, a plan showing the effects dotted in with the interconnecting sea water, condensation and gas lines plainly indicated.

The individual effects are constructed as indicated in Plates IV and V, and may be described as follows, viz:

The evaporating tubes toward the steam end open through the tube-plate partition, in which they are firmly expanded (without annealing). The other ends of the tubes open into a floating head or box, the front wall of which is a removable plate. The tubes are quite free to expand or contract independently of the shell of the effect. The tube plate, tubes and floating head may be taken from the body en masse, through the opened head of the steam end after removing the bolts which hold the tube plate to the body flange. The tubes are staggered vertically, but not horizontally or diagonally, and may be cleaned by scaling irons if ever necessary. The heads of the effects swing on hinges, and are held closed by swing bolts. On the under side is a specially-designed centrifugal circulating pump located midway between the ends of the body.

Steam, or vapor from a hotter effect, enters the steam end, thence into the tubes, in which it is condensed by and causes evaporation from the sea water, which is circulated over the tubes by the circulating pump. The resulting vapors escape through a baffle plate into the "vapor end" and thence away from the effect at the top. A diaphragm which serves as a baffle separates the vapor end from the rest of the shell. At the top of this diaphragm is a hole through which the vapor enters, being deflected downwards by a hood marked in the plate "Separator." Below this hood is a pan in which are placed inclined strips of copper to prevent any salt water which may be carried over into the pan from splattering and thus becoming entrained.

The condensation from the steam inside the tubes flows either into the "steam end," or into the floating head, depending upon the inclination given to the tubes by the motions of the ship. What flows into the floating head finds its way

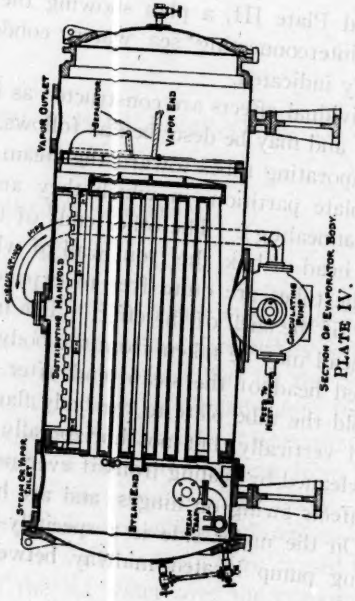


PLATE IV.

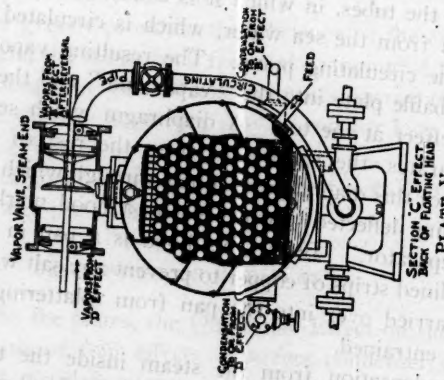


PLATE V.

through the inclined pipe at the bottom into the steam end. From the steam end the condensation escapes through the steam trap to the steam end of the next coolest effect or to the

surface condenser, with the exception that that from effect A, which is always the hottest effect, is taken away by itself for boiler feed, as it is more or less fouled by oil or odors contained in the steam used for evaporating.

The circulation of the sea water over the tubes is a deluging shower, maintained by the centrifugal pump. The circulation is independent of ebullition, and there is no depth of sea water on the tubes through which vapors must force their escape.

The small quantity of sea water in the body is indicated. It is comprised by that in the body beneath the tubes plus that flowing over the tubes.

The perforated distributing plate above the tubes is formed in sections for convenience in handling. It has one row of holes 3/8 inch in diameter above each vertical row of tubes. There is an inch space between the distributing plate and the tube plate, through which there is a heavy flow of solution upon and down the surface of the tube plate, which prevents matter caking on it. There is also an inch space on each side of the distributing plate. The flow of the solution over the side edges of the plate carries with it the particles of scale and what not that may come up with the circulating salt water, and prevents clogging of the perforated plate by them. These matters pass away with the brine discharging from the body, and in the case of a Multiple Effect finally leave the apparatus from the last effect.

The ~~in~~non-condensible gases in the vapors or steam collect in the floating head, and are continuously withdrawn from the same through the nine tubes in the horizontal row near the middle, which tubes open into a manifold fastened on the tube sheet and having one compartment for each tube. From below, each compartment is drained by 3/8-inch pipe, which is trapped by opening below the surface of the condensation held in the chamber by its steam trap. From above, each compartment is connected by a small vent pipe to a vent manifold which leads outside the steam chamber. This vent manifold of each of the effects B, C and D, opens back into the effect in front of the tube plate, and the combined gases vented finally reach

the condenser with the vapors from the coolest effect and are removed by the air pump. The vent manifold from the hottest effect A, is connected to the auxiliary condenser in the engine room, instead of into the space in front of the tube plate, so that any odors in the gases, which came with the steam, may not pass into the distillate.

To form the quadruple effect four effects are placed side by side with the circulating pumps in line, all on the same line of shafting. They are driven by a direct-connected 25-H.P., 115-volt, D. C. motor, which ordinarily uses about 85 ampères, or 13 H.P. for the circulating pumps. There is a flexible coupling between the motor and the shaft of the pumps. Due perhaps partly to the weakness of the deck, and to the drag of the belt which for some months drove it from the circulating-pump engine, this pump shafting is considerably out of line, and absorbs more power than it should.

Distillate pipes connect the steam ends of the adjacent effects B and C and C and D, and the steam ends of B and D each has a valve-fitted connecting pipe to the surface condenser.

A sea-water line leads from the condenser overflow through the steam end of A effect as a heating coil, and then by branches either into A effect or into C effect. When operating as a quadruple effect all the sea water evaporated first enters A effect, the branch to effect C is used only when C and D are operated as a double effect.

The circulating pump of effect A has sea-water discharge line with a branch leading into C, and another leading into B. The latter is used only when A and B are operated as a double effect. The pump of effect C has a discharge line having one branch that leads into B, and another that leads into D. The pump of effect B has a discharge line having one branch leading into effect D, and another into the atmosphere, which is the brine discharge for the apparatus when B is the coolest effect. The pump of effect D has a sea-water discharge with one branch leading into effect B, and another into the atmosphere, which is the brine discharge for the apparatus when D is the coolest effect.

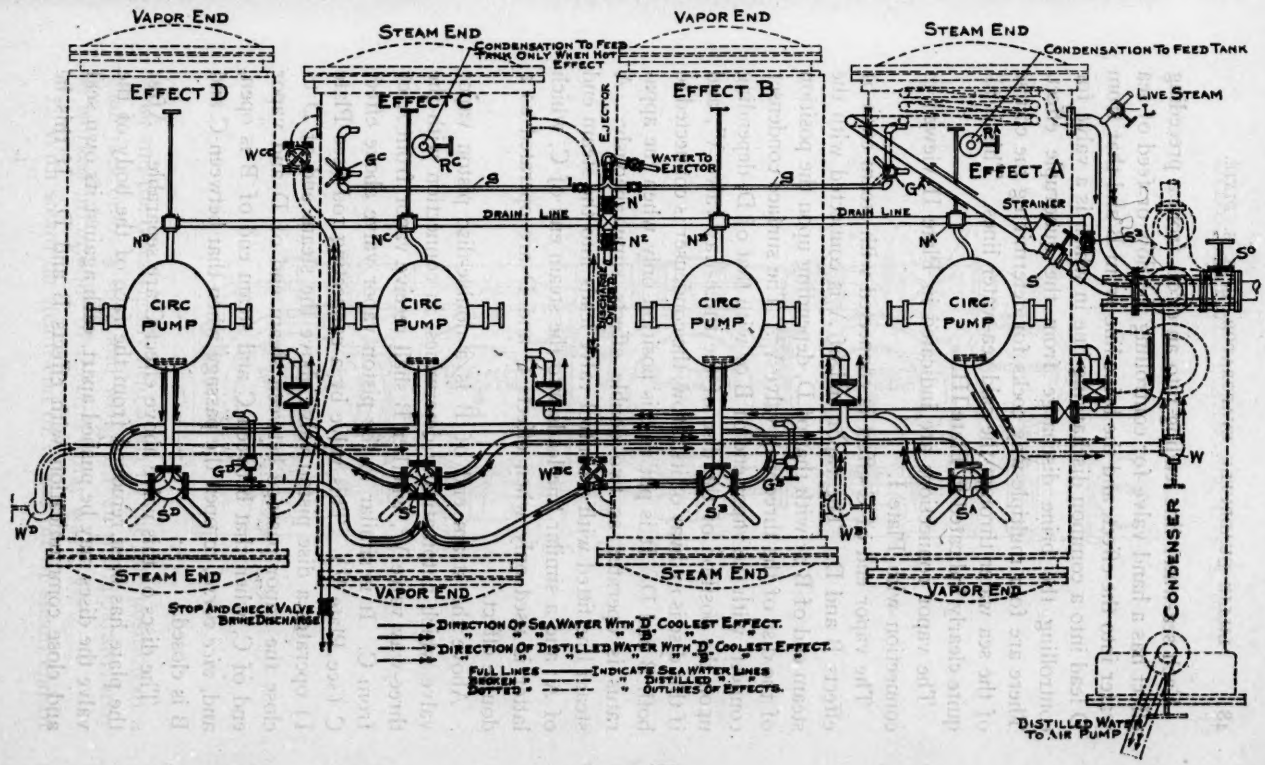

VAPOR END
STEAM END
EFFECT D
EFFECT C
EFFECT B
EFFECT A
CONDENSATION TO FEED TANK ONLY WHEN NOT EFFECT
CONDENSATION TO FEED TANK
LIVE STEAM
EJECTOR
WATER TO EJECTOR
DRAIN LINE
STRAINER
CIRC PUMP
CONDENSER
STOP AND CHECK VALVE BRINE DISCHARGE
DISTILLED WATER TO AIR PUMP
DIRECTION OF SEA WATER WITH "D" COOLEST EFFECT.
DIRECTION OF DISTILLED WATER WITH "D" COOLEST EFFECT.
FULL LINES INDICATE SEA WATER LINES
BROKEN " " DISTILLED " "
DOTTED " " OUTLINES OF EFFECTS.

PLATE III.

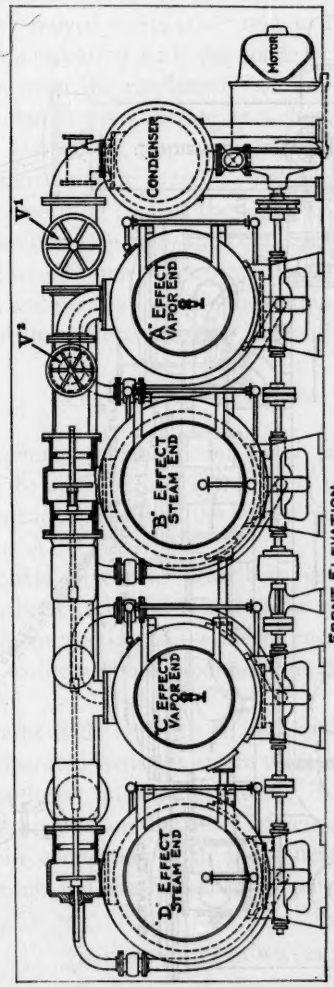
Each sea-water line leading into an effect from a preceding effect has a hand valve for controlling the flow or feed of sea water into the effect, and the brine line from B and that from D lead into a common discharging line in which is a valve for controlling the brine discharge from the quadruple effect. There are four multiple-way cocks for determining the course of the sea water through the said sea-water lines. This is all quite clearly indicated in Plate III.

The vapor connections are indicated in Plate II viewed in connection with Plate I.

The vapor end of C effect is connected with steam ends of effects B and D. The vapor end of A is connected with the steam end of B or with that of D, depending upon the position of the disc of the three-way valve V^2. The surface condenser connects with the vapor end of B or with that of D, depending upon the position of the disc of the three-way valve V^1, and if this disc is midway of its throw, the condenser is connected to both B and D. It is put in this position only when the apparatus is operated as two double effects simultaneously. A steam line fitted with a control valve leads into the steam end of A; and a similar line leads into the steam end of C, which latter is used only when effects C and D are operated as a double effect.

Above the steam end of B is a double-disc piston vapor valve which automatically determines, in connection with the three-way valve V^2, whether B shall receive vapor from A or from C. It is similar to the piston vapor valve above effect C (see Plate V). This valve by a connecting rod (see Plate I) operates a disc piston valve above the steam end of D to close the vapor passage between steam end of D and vapor end of C, when that between C and steam end of B is open, and, *vice versa*, to open the passage when that between C and B is closed.

The discs of this valve above effect C are separable. After the plate has been removed from the face of the body of the valve the discs may be pushed apart, each against its own seat and close communication with effects B and D. If this be



FRONT ELEVATION

PLATE I.

done, and the discs rigidly held apart by the interposition of a small jack or by a strut and wedges, then the apparatus may be worked in any one of the following ways, viz:

1. With steam on steam end of C and off of steam end of

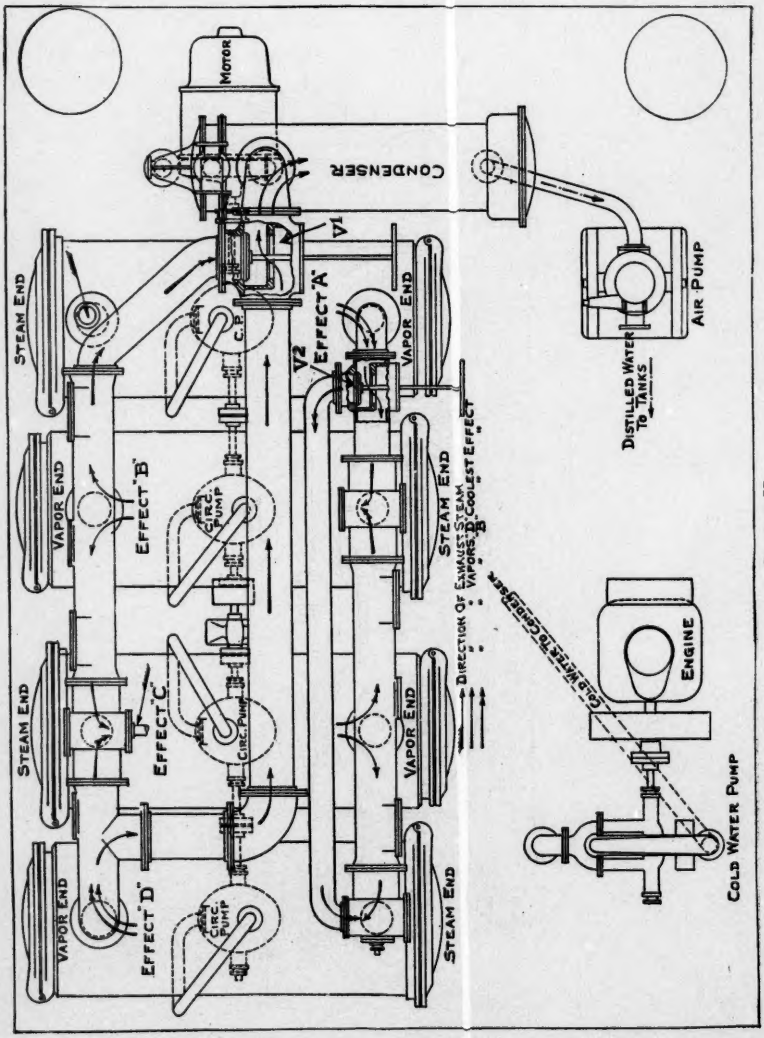


PLATE II.

A, and the vapor valves, including V^1 and V^2, in the positions indicated in Plates I and II, the effects C and D may be operated as a double effect with the effects A and B open for inspection or other purpose.

2. With steam on effect A and off of effect C, and with the vapor valve V^1 moved to its other seat to put the vapor end of B into communication with the condenser, and close communication between the condenser and the vapor end of D, the effects A and B may operate as a double effect with the effects C and D open for inspection or other purpose.

3. With steam on both A and C, and with valve V^1 moved into its middle position so that the vapor ends of both B and D are in communication with the condenser, effects A and B and effects C and D may be operated simultaneously as two double effects and greatly increase the output of distilled water over the quadruple-effect capacity, but with less economy.

METHODS OF OPERATION.

The arrangement of steam and water piping is such that the plant may be used—

(1) As a quadruple effect, the vapors passing in sequence A, B, C, D or A, D, C, B.

(2) As double effects, as described just above, A and C being the two hot effects and B and D the cool effects. There is a live-steam connection to the steam ends of A and C and a connection to the auxiliary exhaust line of the ship leading to A.

The apparatus is designed to be ordinarily used as a quadruple effect, operated with low steam pressure, 5 pounds above atmosphere or lower, in the first effect. To obtain the necessary lower pressures in the other effects the small condenser is used in connection with the independent centrifugal circulating pump and the Edwards air pump.

TRACING OF FEED WATER.

The sea-water feed passes first as cooling water through the condenser of the evaporator plant. Part of the discharge from the condenser goes overboard and part passes into A through a feed heater in the form of a coil of copper pipes

placed in the steam end of that unit. This water enters under a pressure of about seven pounds from the condenser circulating pump. From the feed heater it passes into the shell of A. There the circulating pump of A continually passes part of this water through the circulating pipe, to be showered over the tubes, and discharges part of it into the shell of C, where it circulates as in A, the part which is discharged from C passing into the shell of either B or D, whichever is being used at the time as the second hottest effect. There it circulates as before, part passing to the coolest effect, where the same circulation takes place and the discharge brine goes overboard.

The courses of the sea water and of the distilled water are indicated by the arrows on Plate III.

The courses of the vapors are indicated by the arrows on Plate II.

SCALING BY REVERSAL.

The automatic valves placed in the vapor lines permit the sequence of units to be quickly changed. The change in temperature produced by this reversal is supposed to prevent the formation of scale in the effects concerned by cracking off whatever scale may have been formed. This reversal is accomplished by shifting two control valves V^1 and V^2 placed over A effect. The necessary variation in the flow of feed water is accomplished by shifting the multiple-way cocks under the effects concerned. On Plate III the cocks are indicated in the position for B, the hottest effect, and D, the coolest. To shift the feeds to D, the hottest, and B, the coolest effect, the levers of the cocks are moved into the dotted-line positions, with the exception of the cock under effect A, which always remains in the position shown excepting when A and B are operated as a double effect, then the lever of this cock is moved into the dotted-line position.

With reversals at intervals of four hours each it is found that after long periods of use the capacity is but little reduced when distilling sea water. The scale in the reversing effects B, C and D seems to reach about 1/64 inch in thickness for cracking off. In A effect it gradually increases to about 1/32

inch in thickness. This scale is calcic sulphate. It may be removed completely and satisfactorily by treatment with dilute solution of sodium carbonate, followed by water carrying a little commercial muriatic acid. This was done as an experiment in the manner herein described under the division "Tests."

Vapor reversing is limited to the three-cooler effects B, C, D. The construction might have been such as to also include A effect, in which case A and D effects would have alternately been the hottest and the coolest effect, but it was feared that the distillate leaving the coolest effect would be too much contaminated by oil which, while the hottest effect, might be deposited in its tubes from the exhaust steam which was to be employed for evaporation. Consequently it was determined to follow the design which made A always the hottest effect, and which led all the sea water first into the A effect and from it into the reversing effects, whereby the salt water would be in its dilutest condition in the hottest and non-reversing effect A, *i. e.*, in the condition least likely to form incrustations.

EVAPORATORS.

Rated capacity per 24 hours, gallons	25,000
Heating surface, total square feet	960
Diameter of tubes, inches	2
Length of tubes, inches	62
over all, feet	9

CONDENSER.

Cooling surface, square feet	465

CIRCULATING PUMP.

Single engine diameter of steam cylinder, inches	7
Stroke, inches	7
Diameter of runner, inches	26
body circulating-pump runners, inches	13

EDWARDS AIR PUMP.

Diameter of steam cylinder, inches	4
air cylinder, inches	10
Stroke, inches	8

Weights.

Quadruple effect and parts, pounds	39,700
Surface condenser, pounds	6,050
Edward's air pump, pounds	2,200
Motor, pounds	2,200
Total pounds	50,150
Sea water in the four bodies, pounds	4,000
condenser, pounds	500
Total sea water, pounds	4,500
Sturtevant engine, pounds	2,550
Centrifugal cold-water pump, pounds	1,500
Total	4,050
Total weight, operating conditions, pounds	58,700

The space occupied is about one-half of that occupied by the Navy type of same rated capacity, and the weight is about 30 per cent. less.

TESTS.

The object of the test was to determine the quantity of water distilled per pound of steam used; the quality of the water distilled; the capacity of the plant; the feasibility of operating the plant as that of one or two double effects, and the reliability of the plant and the best method of operating.

The tests were conducted as follows:

For measuring the water made four tanks were used, each holding 250 gallons. These tanks were filled from the evaporator air-pump discharge and were fitted with drains, leading to the ship's tanks. When a tank was filled the air pump discharge was shifted to an empty tank, and, after being tested for salinity, the filled tank was drained to the ship's tank.

The readings of all pressures lower than atmosphere were taken from a mercury column. After the first four tests the gage and temperature readings were taken every half hour.

Fifteen tests were run, as follows, the tabulated results being shown in Table 1.

1. A 72-hour capacity test. During this test the course of

the vapor in the three coolest effects was reversed every four hours.

The gas ejection from the A effect was discharged overboard.

One 250-gallon tank of water, which was found to contain fourteen grains of chlorine to the gallon, was run overboard.

Steam from the ship's auxiliary-exhaust line was used, with enough live steam to bring the pressure up to 5 pounds per square inch above atmosphere. All possible vacuum was carried in the condenser.

2. A 6-hour economy test with gas ejector overboard, 5 pounds pressure in steam end of A, and all possible vacuum in condenser.

3. A 4-hour economy test with same conditions as in (2), except discharge from gas ejector was measured.

4. A 4-hour economy test with atmospheric pressure on A, all possible vacuum in condenser and gas ejector overboard.

5. A 4-hour economy test with atmospheric pressure on A, 24-inch vacuum in condenser, and gas ejector overboard.

6. Same as (5), except a vacuum of 20 inches in the condenser.

7. Same as (3), except the gas ejector discharged into vapor end of A, instead of overboard.

8. Same as (3).

9. A 4-hour economy test, with all gas ejectors shut off. This test was discontinued, owing to the material decrease in output due to the accumulation of air in the bodies.

10. Same as (5), except 5 pounds pressure on A.

11. Same as (6), except 5 pounds pressure on A.

12. A 4-hour economy test, with 6-inch vacuum in steam end of A, all possible vacuum in condenser, and gas ejector led to ship's auxiliary condenser.

13. Same as (12), except 24-inch vacuum in condenser.

14. A 4-hour economy test to determine the increase in economy due to scaling the tubes.

15. A 6-hour capacity test, 5 pounds pressure on A, all possible vacuum in condenser, and gas ejector led to ship's auxili-

ary condenser, to determine the increased capacity due to clean tubes.

The steam used in the A effect was condensed and weighed.

Between tests Nos. 13 and 14, the tubes were scaled, by boiling with a solution of sodium carbonate, washing and then circulating a solution of hydrochloric acid over the tubes.

Previous to starting the tests 327,750 gallons of water had been distilled since the tubes were last scaled, and up to the time of scaling 510,500 gallons had been distilled. The scaling took about ten hours, and, before scaling, the thickness of the scale was measured and found to be only 1/32 inch thick in the A effect, and about 1/64 inch in the other three effects.

METHOD OF OPERATION.

The following method was found to give the best results. To operate as quadruple effect, D coolest effect, starting with apparatus empty and all mechanism shut down.

1. Start condenser circulating pump.

2. Start air pump; get vacuum of 12 inches to 16 inches in condenser.

3. Set cocks S^a, S^b, S^c and S^d, Plate III, in salt-water line to bodies so that water goes to the bodies in the following sequence: A, B, C and D, filling the bodies until about 2 inches of water shows in the gage glass.

4. Start body circulating-pump motor.

5. Turn steam on A effect, using either exhaust or live steam.

6. Set small vapor-control valve (Plate II) so that the vapor from A effect passes to the steam end of B. Set large vapor-control valve so that vapor passes from the D effect to the condenser.

7. Open condensation valves W^{bc}, W^{cd}, W^d (Plate III), so that the water of condensation passes from the steam end of B to the steam end of C, thence to the steam end of D, and thence to the condenser.

8. Open all gas ejectors from steam end to vapor end, except that on A, which connect to the ship's auxiliary condenser.

9. Open valves to water seals on body circulating pumps.

Reversing the flow of vapors; the plant being in operation in sequence, A, B, C, D, to change to A, D, C, B.

1. Shift small vapor-control valve so that the vapor from A goes to the steam end of D.

2. Shift the large vapor-control valve so that vapor from B goes to the condenser.

3. Open valve W^b on condensation line from B effect to condenser, and close valve W^d on condensation line from D effect to condenser.

4. In order to discharge brine from B as coolest effect, it is necessary to choke down on the circulating valve to this effect. The circulating valve on D effect would then be open wide.

Whenever the plant is to be shut down steam is shut off A effect and air pump stopped. The valve on brine discharge is opened wide, and the plant washed out with cold salt water for half an hour.

When the plant was clean, the capacity was found to be over 25,000 gallons per day.

The formation of scale is much less rapid than in the Navy type of evaporator.

The capacity is only slightly reduced after long usage without cleaning.

During one month, when the ship was at anchor, the evaporators were used for seventeen days and were shut down the remainder of the time, the other auviliaries of the ship being in constant use. A careful account was kept of the coal consumption each day, from which it was estimated that nearly seventy-four (74) pounds of fresh water were made per pound of coal used. This remarkable result is due, of course, to the use of exhaust steam as the heating agent. The only increase in coal consumption was due to the auxiliaries of the evaporating plant and to a possible increase in the back pressure on the other auxiliaries. From actual results it was found that the

TABLE I.

No. of test.	Date, 1912. July-August.	Duration of test, hours	Evaporator Circulating Pump, R.P.M.	Condenser Circulating Pump, R.P.M.	Air Pump, Double Strokes per Minute.	Barometer	Pressure, lbs. gauge "A"	VACUUM in inches of mercury "B"	"C"	"D"	Condenser	Gas Ejector	TEMPERATURES Atmosphere	Condenser Discharge	Brine Discharge	Water Distilled	Feed Water	Saturation of Brine Discharge	Salinity of Distilled Water, grains per gal.	Steam used, gallons.	Water Distilled, gallons	Pounds of Water distilled per pound of steam used.
1	15-18	72	745.5	430.8	142.8	30.16	5.0	6.52 20.8	15.3 15.4	20.9 7.43	26.07		94.0	81.7	171.1	98.0	186.6		.648		71838	
2	21	6	745.7	385	142	30.14	5.0	20.8 7.375	15.5 15.12	8.5 21.1	25.96		98.3	87.7	148.0	103.7	192.5	5/32	.6	2213.9	6106.9	2.758
3	21	4	745.0	335	145.5	29.94	5.0	5.625 19.5	14.75 13.0	20.9 5.5	26.06		94.0	86.8	142.0	102.0	194.4	5/32	.4	1293.1	3988.0	3.084
4	22	4	746.2	401.2	138.5	29.93	0.0	21.22	16.88	12.68	25.08		94.0	89.0	135.0	100.5	177.0	5/32	.4	1039.5	3132.5	3.000
5	23	4	744.0	369.0	104.0	29.96	0.0	10.5	15.4	19.75	24.0		98.3	100.8		116.8	195.5	5/32	.4	809.9	2608.4	2.898
6	24	4	745.0	363.8	106.0	29.75	0.0	8.28	12.6	16.5	20.06		99.5	144.0	159.5	141.0	191.7	5/32	.744	597.7	1949.0	3.270
7	25	4	745.0	403.8	128.5	29.70	0.0	22.78	18.4	13.31	26.53		96.7	81.75	124.5	93.75	178.3	5/32	.6	1002.1	3120.4	3.110
8	25	4	747.0	393.7	124.5	29.68	0.0	11.62	17.31	21.56	26.37		99.0	80.0	129.7	94.75	184.0	5/32	.4	1158.3	2960.8	2.556
9	26	Test was discontinued on account of reduced capacity.																				
10	27	4	749.4	413.7	138.7	29.87	5.0	5.53	12.06	18.12	23.78	5.6	96.5	92.2	157.2	116.5	190.2	5.2/32	.4	1178.5	3084.3	2.617
11	28	4	750.0	383.1	117.2	29.94	5.0	14.56	9.41	4.44	20.06	6.0	95.4	144.5	160.2	150.0	201.0	5/32	.4	862.86	2500.0	2.897
12	30	4	750.0	364.3	116.3	29.76	vac. 5.64	14.5	18.04	21.6	25.82	10.	94.3	74.6	119.4	86.6	186.6	5.1/32	.4	738.75	1966.8	2.662
13	1	4	750.0	392.5	117.0	29.93	vac. 5.56	21.03	17.78	14.16	24.22	10.	100.	119.0	138.2	125.2	187.7	4.9/32	.4	698.89	2120.4	3.032
14	3	4	750.0	425.6	128.4	29.89	.563	6.28	12.03	18.69	25.31	9.9	101	79.57	139.5	109.7	179.0	4.8/32	.575	1416.8 42.26	4030.1	2.844 2.762
15	4	6	750.0	429.3	140.3	30.09	5.0	14.25 1.68	7.45 9.71	4.35 16.39	25.44	9.3	96.2	79.75	143.0	105.3	181.1	4.9/32	.4	2685.0	6918.7	2.576

In column headed "Temperatures, Feed Water," the temperatures given are those after leaving the feed-water heater. The temperature of the sea water was about 66 degrees F.

back pressure in the auxiliary exhaust line was not increased, but, on the contrary, was decreased, thereby reducing the steam consumption of the various auxiliaries.

This latter result may be explained by the fact that the auxiliary-exhaust line is too small to handle the exhaust from the auxiliaries, consequently keeping a high back pressure on the auxiliary-exhaust line. When the evaporating plant is in use it acts as an additional condenser, and takes a considerable amount of the steam that otherwise would have to flow through the auxiliary exhaust to the condenser.

Recently, while the ship was at anchor for two days, a total of 48,250 gallons of water was distilled which averaged .21 grains of chlorine to the gallon, and the total coal consumption of the ship was 19.3 tons. If all the coal had been used for distilling purposes alone the result would have been 9.3 pounds of fresh water per pound of coal, which heretofore would have been considered very good results.

The plant is more complicated and requires more careful attention than the Navy type; the liability to breakdown is slightly greater, and it is more difficult to repair, but this should be considered with the fact that it has more functions than the Navy type.

THE ARLINGTON RADIO STATION.

By D. W. Todd, Lieutenant Commander, U. S. Navy, Member.

There are at present probably but six so-called high-power radio stations in operative condition, viz: Clifden, Ireland; Glace Bay, Nova Scotia; Nauen, Germany; Coltano, Italy; Sayville, Long Island, N. Y.; and Arlington. The last named is the latest to commence operations. It is the largest and most powerful of the forty-eight stations of the Navy's Coast System; and, containing the offices of the Superintendent, is the controlling station of the Naval Radio Service.

The Bureau of Steam Engineering had the coöperation of the Bureau of Yards and Docks in the erection of the station, the latter designing the buildings and towers and inspecting the work during erection.

CONTRACT FOR RADIO APPARATUS.

In October, 1908, the National Electric Signaling Company of Pittsburgh, formed to develop radio apparatus covered by the patents of Reginald A. Fessenden, offered to the Department, through the Bureau of Equipment, a high-power radio set, guaranteeing ranges far greater than those of any other apparatus in existence, together with entire freedom from interference and entire secrecy. As a result of this offer a schedule was prepared, and bids received from a number of companies for a high-power station to be erected in Washington or vicinity. They were opened on January 28, 1909. The bid of the National Electric Signaling Co. was adjudged to be the most advantageous to the Government, and a contract was signed, dated May 7, 1909. By its terms the Navy Department was to erect a station with a 600-foot tower or mast,

and the company was to install their apparatus in it; at the same time the Company was to equip two scout cruisers with sets in advance of the completion of the station, and preliminary tests were to be made between them and the Company's station at Brant Rock, Massachusetts, for which a rental was paid by the Department. The 100-kw. set for the proposed Washington station was installed there.

BRANT ROCK STATION AND SCOUT CRUISER TESTS.

The Brant Rock station was one of a pair built for trans-Atlantic communication. Before such communication could be satisfactorily established, the mast of the station in Scotland was blown down by a gale, and has not been re-erected. This left the Brant Rock station free for other experimental work and the Navy's tests of the high-power set and the two 10-kw. sets installed on the scout cruisers *Birmingham* and *Salem*. Partly on account of the insufficient boiler power of the Brant Rock station, 60 H.P. for a 100-kw. set, and the height of the mast, 420 feet, the tests were inconclusive, as far as helping to complete the contract at an early date was concerned. They were of value, however, in that they furnished data from which Dr. Louis W. Austin evolved an interesting and useful formula connecting distance, height of aerial, and radiation current. The character of the tests and the formulas are described by Dr. Austin in a bulletin of the Bureau of Standards (Vol. vii, 1911, p. 315).

DELAY IN FINDING SITE.

There being no Congressional authority to expend any part of the appropriation available for radio stations and apparatus for the purchase of land, a long search was made for sufficient land already belonging to the Government on which to build the station. At one time the Washington Monument was urged as a support for the "umbrella" aerial contemplated, and it would have served admirably for the purpose, barring the fact that it is not quite 600 feet in height. The

upper parts of the wires near the shaft would have been practically invisible, except to observers at the windows in the top, and the lower ends would be anchored at least two city blocks from the base. Only the leading-down wires from top to station building would be evident.

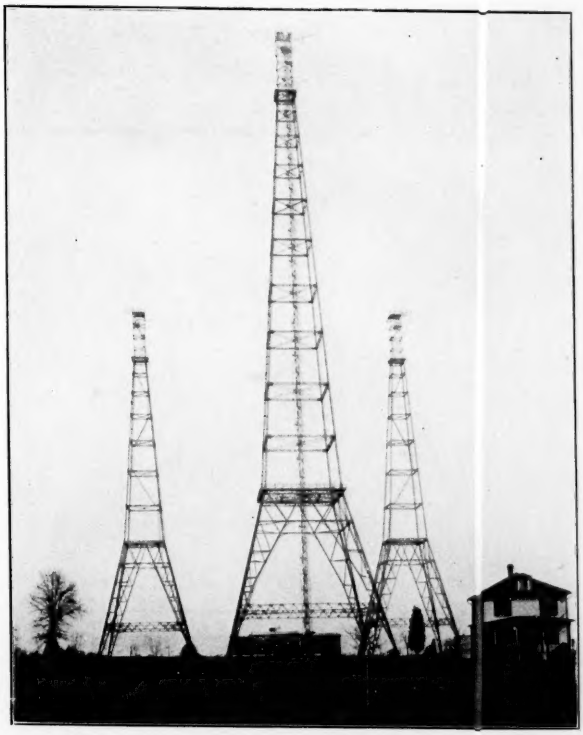
Five sites were examined. Of these, one in the Soldiers' Home grounds was considered most favorable, but it was found that the tract was restricted to use for the purposes of the Home exclusively. The present site was obtained through the courtesy of the War Department and is quite suitable. It is now, by Act of Congress, a naval reservation.

THE SITE.

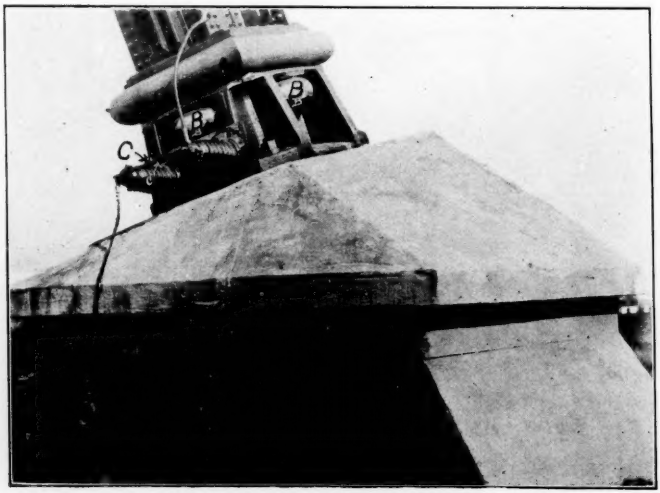
The station is situated in the Virginia hills, near Arlington, on the southwest corner of the Fort Myer Military Reservation, about one mile from the buildings of the fort and from the gate of the Arlington Cemetery, and four miles from Washington. It is reached by the electric cars of the Washington-Virginia Railway Company, in twenty minutes from the Post Office, via the Highway Bridge to Radio, or, less easily, via the Aqueduct Bridge and Fort Myer to Hatfield Junction. There are 13.4 acres in the site, which is on comparatively high ground, 190 feet above sea level. A small stream flows past it, the water of which will be available to keep the ground moist during the summer months. The soil is a mixture of clay and gravel.

THE TOWERS.

As a sufficient area for stretching the wire of an umbrella aerial could not be easily obtained, and on account of the superiority of the "flat-top" over an umbrella supported at the same maximum height, self-supporting steel towers were decided upon. The number, three, was chosen for the following reasons: Two towers would not permit a sufficient spread for the aerial, and four towers could not be built with the money available. The height of one tower, 600 feet, was



VIEW A.—NAVAL RADIO STATION, ARLINGTON, VA.
(LOOKING EAST.)



VIEW B.—FOOT OF TOWER, SHOWING INSULATION.

fixed by the terms of the contract. The other two would have been given the same height were more funds available. Their height, 450 feet, measures the latter. The arrangement of the towers shown in View A supports a triangular, inclined aerial, whose effective height above the ground exceeds that of an umbrella supported by a single 600-foot tower.

The contract for the three towers was made with the Baltimore Bridge Company, on June 30, 1911. It required that they be complete, except for a final coat of paint, in nine months, *i. e.*, March 30, 1912. They were not entirely finished until December 10, 1912, due to various causes.

The three self-supporting steel towers are of latticed-angle construction. Each leg is insulated as shown in View B, by a block of blue Vermont marble (A), secured by bolts having marble washers (B, B). Insulating blocks and washers were carefully selected to insure freedom from seams and mineral veins; were baked at 200 degrees F., for periods of 24 to 48 hours; tested by the application of an alternating electromotive force of 100,000 volts for periods of one minute, and then varnished. The maximum stress on these blocks is 400 pounds per square inch. Insulating blocks bear on cast-steel bases, each secured by four holding-down bolts, which are in turn anchored in concrete foundations 12 feet square and 8 feet deep, by four channel bars each 4 feet long and 1 foot wide. All interior spaces in marble bases and washers around holding-down bolts are filled with melted sulphur. The marble insulation of each leg is short-circuited and the tower grounded by the lightning switch shown in closed position (C).

600–FOOT TOWER.

The height is measured from center of base plates to top. The base is 150 feet square. At the 150-foot level is the gallery shown in the cut, and 390 feet above this gallery is a smaller one. The tower tapers to this height and the remaining 60 feet to top platform is of uniform cross section, 15 feet square. In the axis of the tower is an elevator shaft, alongside of which is fitted a series of vertical ladders with

platforms about every 15 feet. The elevator is not yet installed. The foot of the shaft is insulated in the same manner as the legs. The elevator hoist engine and the structure containing it will probably also be insulated from the ground. From the top of the tower rises a 50-foot wooden pole. This tower is at the western edge of the reservation, excluding that used for a public road. At the northeastern and southeastern corners of the top platform, braced from the other two corners, are 30-foot outriggers, facing toward the small towers. These outriggers have a number of lashing shackles and eye-bolts for leading blocks for falls or whips which can be handled by a small double-geared hand-winch, secured on the top platform, for working with aerials. It has a drum with gypsy head in the drum shaft and on the crank shaft. The weight of steel in the tower is about 500 tons. All towers were designed to withstand a horizontal pull at the top of 15,000 pounds.

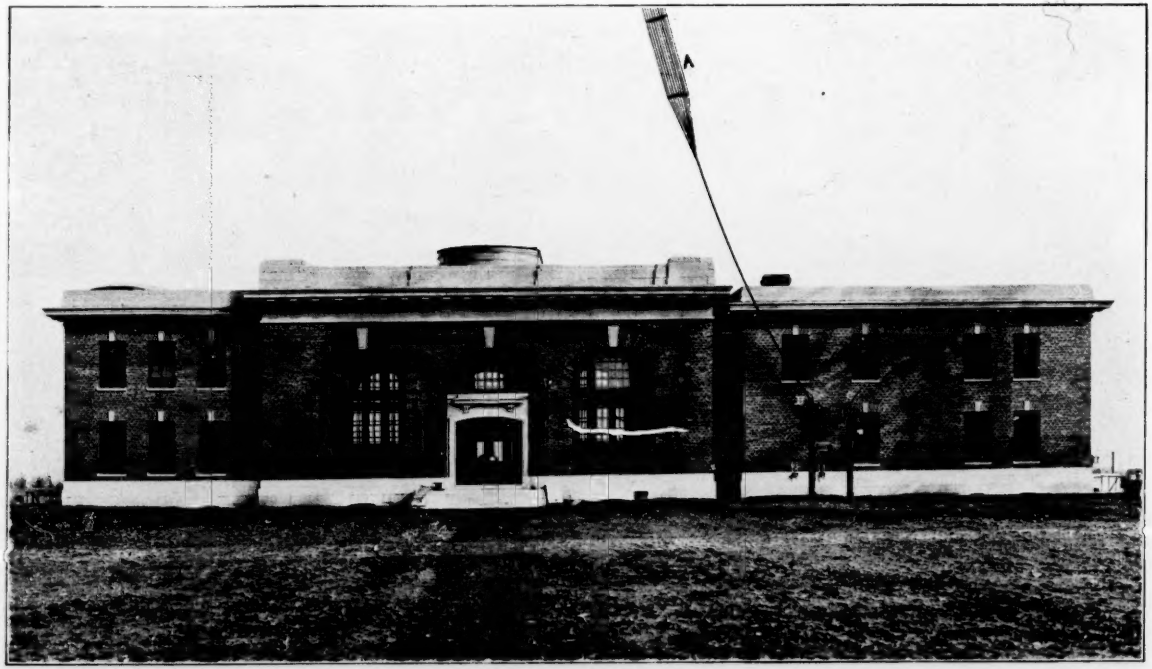
450-FOOT TOWERS.

The centers of the two 450-foot towers are placed at the corners of an isosceles triangle, of which the center of the higher tower is the apex. The base of the triangle is 350 feet on a practically North and South line. The altitude is also 350 feet, about East and West. They are similar in most respects to the large tower, except that the lower gallery is omitted; the vertical ladders are replaced by stairways which follow various diagonal members, passing around the towers several times, the foot of the stairway being a wooden ladder normally lifted from the ground, and the outriggers on the sides looking toward the other 450-foot tower are 15-foot continuations of the sides of the top platforms.

Weight of steel in each of the smaller towers, about 275 tons.

BUILDINGS.

There is a transmitter building, a receiver building and a well house. One other construction outside of these three is a pair of septic tanks in tandem, for disposal of sewage.



VIEW I.—WEST FRONT OF BUILDINGS.

VIEW J.—AERIAL SWITCHES.

The first mentioned buildings extend approximately North and South, parallel to the center line of 450-foot towers (View I). They are entirely separate in order to reduce the transmission of sound and vibration from the transmitter building, containing all moving machinery except ventilating motors, to the receiver building, used for operating, for the finer laboratory work, and for living quarters for the crew. The two buildings are joined by a covered passageway, which is not connected to the transmitter building. The only physical connection is through the conduits which carry lighting and power circuits from switchboard to receiver room.

The buildings are of brick, the outside walls of tapestry brick, with terra cotta trimmings and granite bases, floors and roofs are of reinforced concrete slab construction, supported by framing and columns of steel; partitions are of terra cotta and brick. They have basements throughout. The general dimensions are, approximately, as follows:

Receiver Building: 38 feet wide, 54 feet 6 inches long;

Transmitter Building: 44 feet wide, 97 feet 6 inches long;

Height of buildings from grade to cornice, approximately 33 feet 6 inches;

House over well: 10 by 12 feet.

Nearly all rooms in both main buildings are fitted with porcelain washstands or porcelain or soapstone sinks. The floors of the engine room, toilet and shower rooms are terrazzo; other rooms have pine flooring. The buildings were erected under a contract dated June 29, 1910, with Mr. Arthur Cowsill, of Washington. Contract time, eight months, but the work took fifteen months to complete.

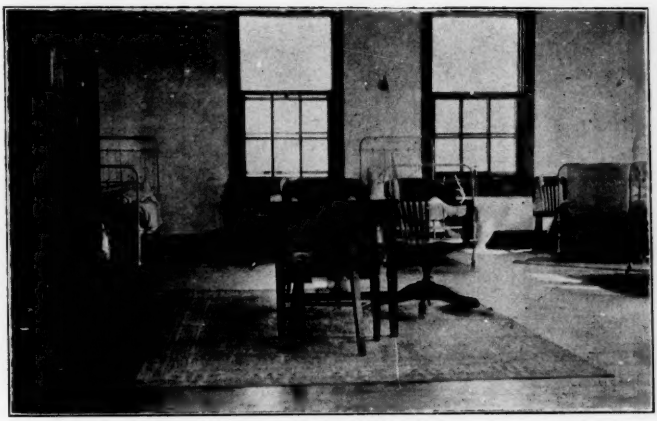
TRANSMITTER BUILDING.

The transmitter room proper, in which is all machinery except the machine-shop tools, is 40 feet by 64 feet in one story, 33 feet from ground level to the eaves. It contains the power transformers (in basement), the transmitter, the switchboards, foundations for a direct-connected, 15-kw.,

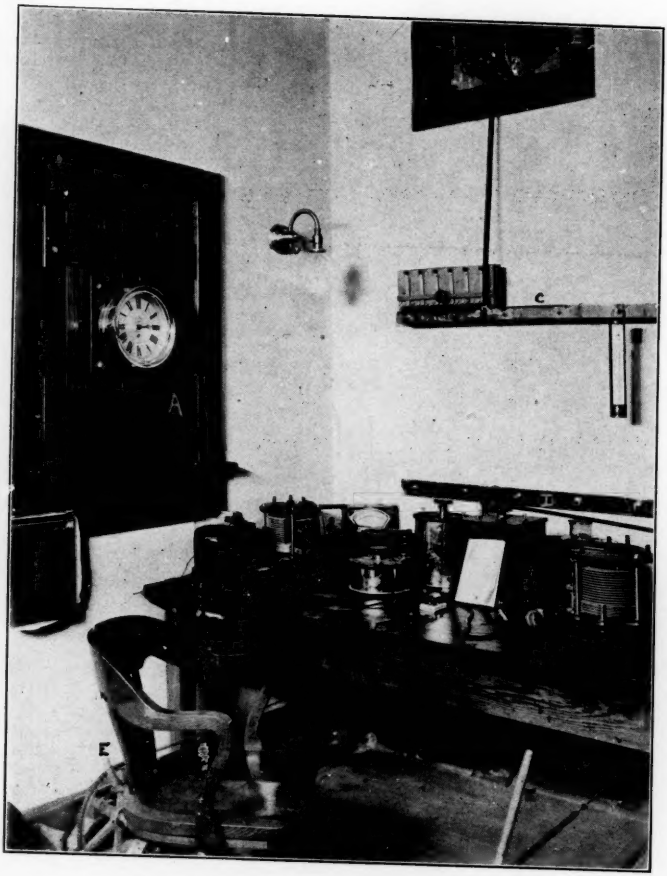
D.C. generator to be run by a heavy-oil engine and a test plate on special foundation. A 10-ton traveling crane traverses the full length of the room on rails 24 feet apart. Considerable space has been left for the accommodation of more machinery, notably a heavy-oil engine for local power. A large open space has been left in the floor for this purpose, partly boarded over to increase floor space. At the northern end of the building is an extension 30 feet by 38 feet, two stories in height. The lower floor has one room for a laboratory and museum; another room of equal size is now used as a machine shop, and contains a 12-inch lathe, a planer, a drill press, a grindstone and emery wheels; and a smaller office at the extreme northern end of the building is a fourth-class post office, recently authorized, named, "Radio, Virginia." At that end of the building is a stairway to the second floor, on which are located three offices for the Superintendent of Radio Service. The stairway continues to the roof, ending in a booby hatch. The tiled roof is flat-topped with a parapet three feet high and extends the entire length of the transmitter building in two elevations. On the roof is a 19,000-gallon wooden tank, 16 feet in diameter, which is filled by an electric pump from the well, 150 feet deep, near the buildings.

RECEIVER BUILDING.

This contains the receiving and operating room, the operator's office, the main laboratory, the office and bedroom of the officer-in-charge of the station, dining room, kitchen, living quarters, and library for the crew. The principal feature of these quarters is a well-lighted dormitory 25 feet by 36 feet (View K). A small library is well supplied with books ordinarily found in a crew's library aboard ship. The staircase ends at a booby hatch on the main roof, which is similar to that of the transmitter building, but not connected to it. In the basement are the heater, laundry, coal bins, store rooms and ventilating motors and ducts for ventilation of receiver room.



VIEW K.—EAST SIDE OF DORMITORY.



VIEW D.—CORNER OF RECEIVER ROOM.

RECEIVER ROOM.

The receiver room has been specially sound-proofed. In addition to an air space between the tiles there is a layer of metal furring, to which is attached Clinton wire cloth made up of galvanized-iron wires with a half-inch mesh. All joints overlap four inches, and are secured together with copper wires, the whole connected to the ground. Walls, ceiling and floor are thus covered, and plaster laid on the wire cloth, on walls and ceiling. The floor is wood, under which is a layer of "Linofelt," then wire cloth, wood sleepers, hollow tiling and concrete, in the order named. The doors are double refrigerator doors, 6 inches thick, with refrigerator door clamps. In addition there are smaller doors of refrigerator type, which may be seen at A, View D, giving an opening through which messages may be passed to and from the operator's office. The room is artificially lighted, and is ventilated by special motors in duplicate, taking air from the end of the building farthest from the transmitter. The air is heated in winter by passing through ducts in which are pipes of the hot-water heating system. In these ducts are felt baffles to prevent the transmission of sound.

The receiving aerial runs through a large composition insulator (B), sufficient for a small transmitter, should it be desired to install one temporarily. The aerial lead is soldered to a copper strip (C), which is separated by a small air gap, not shown in view, from a similar copper strip (D), which is connected to the main ground. Binding posts are provided for attaching a number of independent receiver sets for different wave lengths, which the receiving operator may cut in at will by a switch, called a "tune shifter."

The operator on duty will be practically free from disturbance, as far as noise is concerned. He will communicate with the transmitting room by signaling lamps and with the relief operator in the adjoining office by means of a telautograph. Two heavy tables are supplied for receivers and measuring instruments, a miscellaneous collection of which is

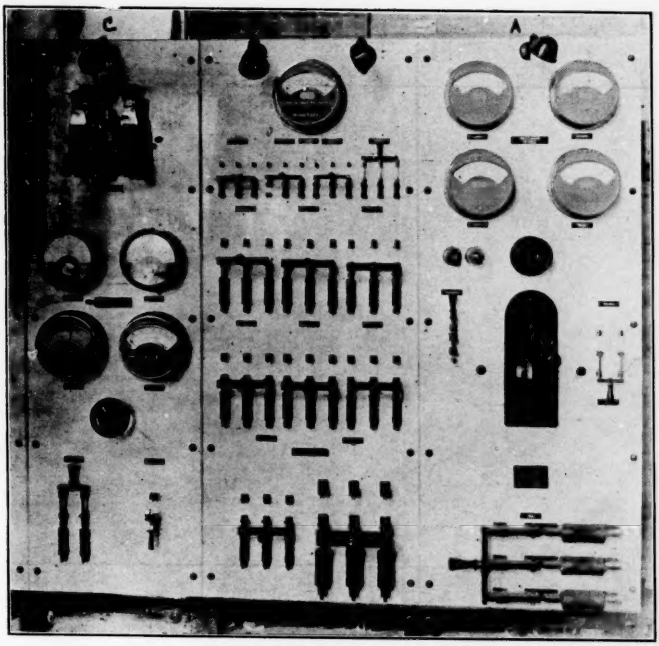
shown in View D, while a heavy stone shelf has been built into the wall for supporting a galvanometer. Levers for controlling aerial switches are close to the operating table (E, E). The transmitter is operated by means of a small sending key. The receiving apparatus originally furnished with the set by the National Electric Signaling Company consisted of variable transformers, inductances and condensers as separate units, with electrolytic detectors. This outfit is not now in use as a whole.

OPERATOR'S OFFICE.

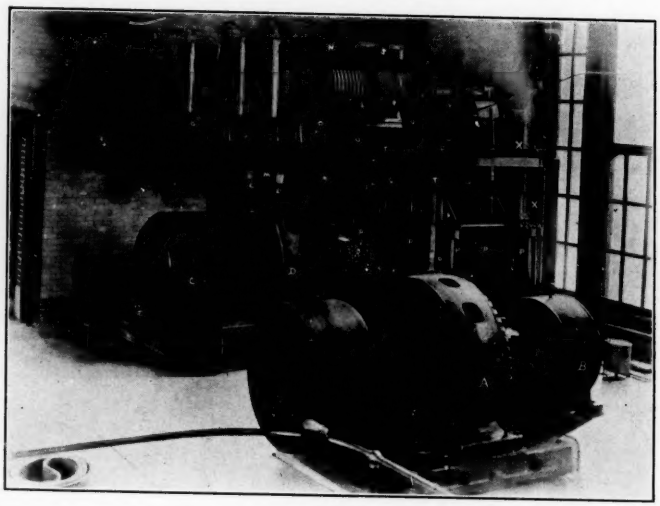
In this room a second operator receives all messages and typewrites them on a special autographic register, which furnishes three copies in one operation and rolls one copy into a locked box as a record copy. On a table is a small "monitor" board, through which six local telephones may intercommunicate or be connected to the City of Washington through two wires, one of which goes to the "West" exchange of the Chesapeake and Potomac Telephone Company, and the other direct to the Division of Operations of the Secretary's Office and to the Bureau of Steam Engineering. There is also a telautograph for communicating with the operator at the receiver, a telegraph key connected to the city offices of both the Western Union and Postal Telegraph companies, and two time-signal relays one for each line.

MAIN LABORATORY.

The laboratory is protected from stray currents and the inductive effects of sending by Clinton wire cloth, in the same manner as the receiver room. Cases will be provided for the finer instruments and special supports for galvanometers on special foundations, independent of the floor. Copper strips from the main ground system are brought up to the level of the work tables at several places. Conduits for leads to the main switchboard are provided so that current may be obtained of any desired character. The room is well lighted and well suited for the purpose.



VIEW E.—MAIN SWITCH BOARD.



VIEW F.—TRANSMITTER.

THE TRANSMITTER.

Power.—The present source of power is the Potomac Electric Power Company's plant at Bennings, D. C. This is led, underground, through the company's distributing station at Fourteenth and B Streets, N. W., Washington, D. C., to the Aqueduct Bridge; thence overhead to within 500 feet of the transmitter room; thence underground to the transformers. The current is 3-phase, 25 cycles, at 6,600 volts, which is transformed into 220 volts. The three transformers, 6 feet high, are in the transmitter-room basement. From these transformers the current is led to the first panel of the main switchboard (View E, A). The second panel (B) is the secondary distribution of 25-cycle current. The distribution, at present, is to the well pump, and to the receiving-room ventilating motors. There are terminals and switches for a D.C. motor-generator set, tower-hoist motors, battery ventilating motors, etc.

The driving power of the 100-kw. generator consists of a 200-H.P., 3-phase, 220-volt, 500-r.p.m., Westinghouse synchronous motor A, View F, having a stationary armature and a revolving field. The field has six poles and is excited by an 8-kw. 110-volt exciter, directly connected to the motor shaft, having also in addition a small squirrel-cage rotor which is used only for starting. The exciter generator, B, also furnishes current to excite the fields of the 100-kw. generator mentioned below, and when the transmitter is not being used it furnishes current for machine-shop tools and for a small air compressor, used for pumping up condensers.

To start the motor a Westinghouse auto-starter is used, consisting of a double-throw oil switch and a three-coil auto-starter transformer. The motor starts as a polyphase induction motor having a coil of the auto-transformer inserted in series in each phase so as to cut down the starting potential until the motor comes up to speed, whereupon the auto-starter is cut out and the motor cut in directly on the mains.

Generator.—The motor drives the generator C, by means of a 19-inch leather belt. The generator runs at a speed of

1,250 r.p.m. and is a 100-kw., 220-volt, 500-cycle machine, having a revolving field of 48 poles excited from the motor exciter and a stationary armature, which may be connected either in series or multiple. Directly connected on the armature shaft is a synchronous rotating gap consisting of a horn-fiber disc 4 feet in diameter and 1 inch thick (View G). On the periphery of the disc is a flat brass hoop, and screwed into this hoop are forty-eight 5-inch copper spokes spaced, at their tips, 3 inches apart, there being a spoke for each field coil. Completely enclosing the rotor is a drum 6 feet in diameter by 2 feet in width, D, and in the top of which is inserted two electrodes in heavy porcelain corrugated insulators. The fixed electrodes are hollow copper tubes, water cooled, water being supplied from tanks overhead (F, F) and kept in circulation by two small electric pumps (G, G).

They are adjustable radially and also the drum, in which the electrodes are inserted, may be revolved through a small arc by a crank and screw arrangement. The adjustment radially is made so that the rotor clears the stationary electrodes about .004 of an inch and the drum is revolved so that when the armature coils are cutting the maximum lines of force the stationary electrodes are a little forward from the center line between two spokes and in this position the rotating gap is in synchronism with the generator, there being then a discharge for every alternation, or 1,000 discharges per second. This adjustment only holds true, of course, when the primary and secondary circuits of the transformer are in resonance.

The spark gap is in two parts, the spark jumping to the rotor at one fixed electrode, the current leaving at the other with another spark. After a few sparks have passed there is a lead of about one inch in the jumping of the spark, with no lag, *i. e.*, sparking from any one moving electrode commences when it is about one inch from either of the fixed electrodes, but there is no sparking after it has passed.

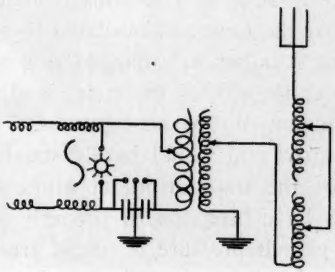
The 500-cycle current is led from the generator to the switchboard C, View E, through a circuit breaker to the trans-

former in basement, where the voltage is stepped up from 220 to 25,000. There are variable impedences in both legs of this primary circuit, to obtain resonance, and one leg is broken by the main key H (View G), around which is shunted a variable resistance. When the key is open some current passes through the grid resistance around it, thus making the work of the generator more uniform. The resistance also prevents excessive sparking at key contacts while sending. At I is a rheostat for regulating direct current of solenoid and at J is a cut-out switch. A small key in operating room controls the solenoid key.

In the secondary leads from the transformer are two sets of inductances in each leg. One set is variable for obtaining resonance, while the other protects the transformer against "kick-backs."

THE CLOSED CIRCUIT.

The diagram shows the arrangement of closed and open circuits:



SENDING CIRCUITS.

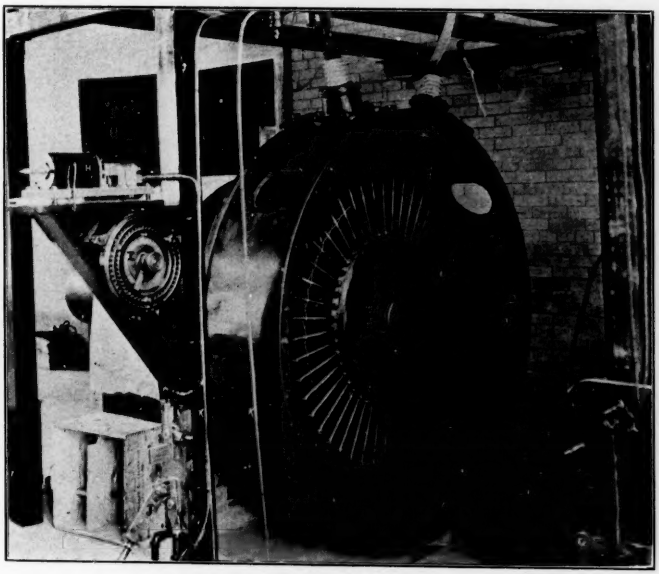
All leads are braided or strip copper, or tubing. From transformer to spark gap and condenser the lead is 00 copper rod K, K (View F), and ½-inch braided copper L. From fixed electrode of spark gap 2-inch copper braid to primary oscillation transformer and to condenser M, M. From primary to condenser 2-inch copper braid and 1-inch copper pipe.

The primary inductance N, in series with the condenser, is a spiral helix of one-inch copper tubing wound on a wooden

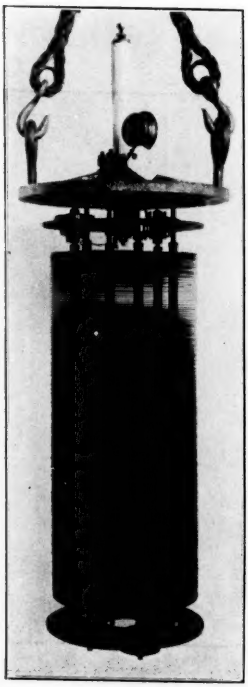
frame to a diameter of about 4 feet. The spark-gap connection and the condenser connections are both adjustable by clips. The helix as a whole can be moved axially with reference to the fixed secondary helix to alter the coupling, by means of a screw operated by a pulley and cord O, O, O.

CONDENSERS.

There are fifteen condensers P, P, of the Fessenden compressed-air type in two sets of seven in series, with one spare ready to be connected in to either set. This type of condenser is suitable for handling high powers, as, in case the dielectric (compressed air) breaks down, it instantly repairs itself. The losses are small as there are no brush discharges. The condenser is made up of a large steel cylindrical tank, in which are sheet-steel circular plates supported by two sets of three rods each, View H. Each alternate plate is connected to the tank itself, while the intervening plates are connected by their supporting rods to a terminal rod led through the cast-steel cover of the tank and insulated by porcelain. The cover of the tank is bolted to a flanged ring at its top and a lead washer under the rim of the cover, and a lead bushing around the insulator, insure air-tightness. The plates are spaced ⅛ inch apart and would hardly stand the voltage of the secondary of the transformer at atmospheric pressure. After the plates have been spaced properly and the tanks charged to 250 pounds pressure, a special treatment is given them to increase the dielectric resistance between the plates. A safety gap is set on the outside of the tank, between the insulated rod and the terminal on tank, the gap being slightly larger than the separation of the plates. The primary current is then flashed on intermittently, to cause sparking inside until the particles of dust are burnt out, when the spark will jump the safety gap. The latter is then widened and the operation repeated until the gap is one inch. During this "burning out" care is taken to have the generator voltage as low as possible. By this treatment the condenser can be made



VIEW G —ROTOR AND SPARK GAPS.



VIEW H.—PLATES, COVER AND INSULATORS OF COMPRESSED-AIR CONDENSER.

so that the safety gap of one inch will break down before the compressed-air dielectric, ⅛-inch wide between plates, is pierced by a spark.

Each condenser has a capacity of .036 M.F. Fourteen units are used in multiple series so as to reduce the potentials, two sets of seven in multiple and the two sets in series. The resulting primary capacity is .126 M.F.

Each bank of condensers has an insulated bus-bar, Q, Q, View F, to which the insulated terminals of condensers are connected by flexible-copper braid and a protective fuse wire. Adjacent tanks are connected by one-inch copper pipe, and the ground connection from the center of the entire group is a 2-inch copper pipe, R. To prevent unequal voltages in the two banks of condensers the bus-bars are connected, through inductances, to 8-inch hollow-copper balls, which are fixed at equal distances from a third similar ball between them. The third ball is grounded.

SECONDARY INDUCTANCE AND LOADING COIL.

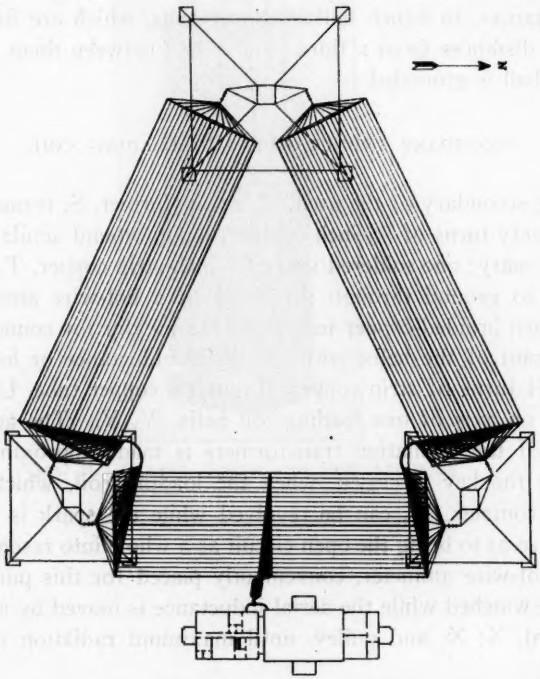
The secondary of the oscillation transformer, S, is made up of twenty turns of ⅜-inch copper tubing, wound similarly to the primary; one soldered lead of 3-inch strip copper, T, T, is taken to ground through the shunt of a hot-wire ammeter. A 2-inch braided-copper lead has a spring clip for connecting any point of the helix with the aerial inductance or loading coil, 54 turns of strip copper, through a copper tube, U, and brush on axis of one loading-coil helix, V, V. The adjustment of the oscillation transformers is made approximately before the key is closed, when the loading coil, which has roller contacts, W, can be revolved while the spark is oscillating so as to bring the open circuit as a whole into resonance. The hot-wire ammeter, conveniently placed for this purpose, can be watched while the aerial inductance is moved by means of cord, X, X, and pulley, until maximum radiation is obtained.

AERIAL LEAD.

This is a 1-inch copper pipe, Y, with fixed connection to aerial inductance, led outside the building through a large electrose insulator, Z, fitted in a plate-glass window 1 inch thick and 5 feet square; from this point, it is connected to one contact of the three-way sending aerial switch on the short pole mentioned above.

AERIALS.

The main aerial is triangular in plan. Two sections, 355 feet long between spreaders, are suspended from the outboard shackles of the main tower to the outboard shackles of the smaller towers. The main section, 240 feet between spreaders, is a flat top "T"-aerial with leading-down wires from the



PLAN OF MAIN AERIAL.

center carried as a fan for 300 feet and then as a cage (A, View I) until wires are brought together to the arm of a three-point lightning and change-over switch, B. The three sections are on trussed pipe and latticed spreaders 88 feet wide, shown in the view of towers. The axis of each is a three-inch galvanized-iron pipe. Spreaders are supported by bridles, in which are turnbuckles for equalizing the strain. Bridles are all carried to a 10-inch ring and suspended from shackles on outriggers through ten large "electrose" insulators. The end of the system is open at the top of the 600-foot tower. The aerial wires consist of twenty-three phosphor-bronze standard antenna wires, each containing seven strands of No. 20 wire. The outer and middle wires are made up of seven single wires seized together to form three cables for taking the strain. The jumpers between the inclined portions of the aerial and the main "T" is made up of twenty-three wires bunched together and guyed clear of the towers. All aerial wires are soldered to the spreaders and have jumpers soldered to bridles; thus all six spreaders and their bridles are parts of the aerial capacity. The natural period of the aerial is 2,170 meters; capacity .0094 M.F. Between the main and the southeast tower is a smaller receiving aerial about 220 feet long, made up of seven wires soldered to 30-foot gas-pipe spreaders. It is a true "flat-top" about 300 feet from the ground with leading-down wires from nearest spreader brought together and taken to the receiving aerial switch, C. This smaller aerial will be used for the secondary station set, as a sending and receiving aerial for local communications. Natural wave length, 900 meters; capacity, .0023 M.F.

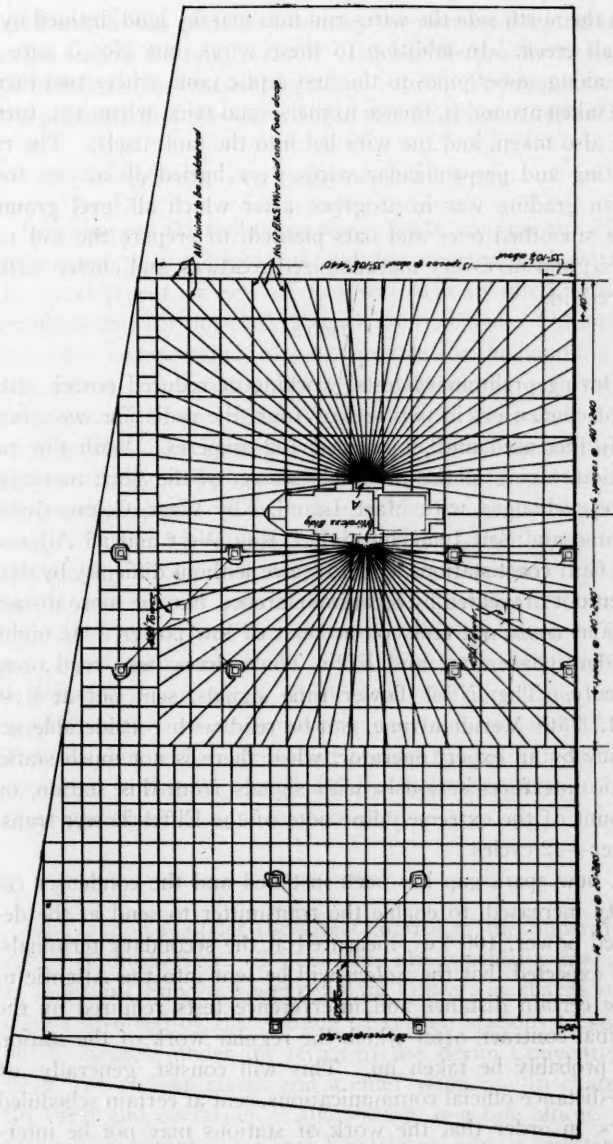
AERIAL SWITCHES.

The switches for both aerials are mounted on short posts opposite the receiver room, View J, and are managed through chain-and-sprocket connections, D, D, D, by the operator. Either aerial can be grounded at will; either can be used for receiving, or the two may be used in multiple for receiving.

The larger aerial is normally used for receiving on wave lengths above its natural period and the smaller one ordinarily for the shorter waves.

THE GROUND.

When excavations for tower legs and buildings were made, bare copper wire (No. 6) was laid in parallel lengths under cement work. These wires were afterward soldered to single wires of the same size, from which copper strips were led outboard through the foundations, at about twenty-four points on all sides of buildings, to an exterior bus-bar formed by two No. 6 bare copper wires entirely surrounding the foundations. To the last named bus-bar are soldered bare copper wires (No. 12), extending perpendicularly to the limits of a square, 480 feet on a side, with the buildings approximately in the center, to boundary wires parallel to the sides of the buildings. These wires are crossed at right angles by others, forming squares of 40 feet on a side, soldered at crossing points. Another system of ground wires radiate from copper plates ⅛-inch thick and 4 feet 6 inches square, on the east and west sides of the transmitter building; that on the west side is buried 6 feet deep, close to the foundations, and is as close to the transmitter as possible. This is cross-connected to a similar plate on the east side, by means of six No. 6 copper wires, which are soldered to the bus-bar wires first mentioned at crossing points. From these two plates No. 12 bare copper wires radiate in all directions to the boundary wires. Near the foot of each tower leg are buried copper plates as lightning grounds, similar to those near the buildings, about four feet deep. Wherever either radiating or perpendicular wires pass near these plates they are soldered to them; also, wherever the wires of the two systems cross the crossings are soldered. On the north and west sides of the 480-foot square a rectangular system of wires stretch to the limits of the reservation, dividing the space into about 300 squares 20 feet on the side, all crossings soldered and all wires touching the 480-foot square soldered to its boundary wires.



PLAN OF GROUND WIRES.

On the north side the wires run into marshy land drained by a small creek. In addition to these wires, one No. 6 wire is led along sewer pipes to the first septic tank, where two turns are taken around it, thence to the second tank, where two turns are also taken, and the wire led into the tank itself. The radiating and perpendicular wires were buried about one foot when grading was in progress, after which all level ground was smoothed over and oats planted, to prepare the soil for grass; and necessary macadamized roadway and cinder walks were laid.

TESTS.

During preliminary tests, working at reduced power, with eight condensers in two sets of four, the radiation was gradually increased until it reached 102 ampères. With this radiation, owing to the favorable season of the year, messages were exchanged with Mare Island, Key West, Colon, Guantanamo and San Juan, by night. Key West and all Atlantic and Gulf coast stations, could receive without difficulty by day, when not prevented by local interference, but the more distant stations could not reply on account of low power. At night, Clifden, Glace Bay, and Eiffel Tower have been read occasionally. The Eiffel Tower time signals, sent out at 6:40 P.M., 75th Meridian time, can be read with considerable accuracy by an expert operator, when there is not much static. Static interferes seriously with signals from this station, on account of the extremely low note of the Eiffel Tower transmitter—42 cycles.

A new spark-gap has been installed and the condenser capacity increased, to enable the transmitter to send at the designed power, 100 kw., measured at the secondary terminals. It is expected that the *Salem* will be sent into the Atlantic to make certain distance and interference tests required by the original contract, after which the regular work of the station will probably be taken up. This will consist, generally, of long-distance official communications, sent at certain scheduled hours, in order that the work of stations may not be inter-

fered with to too great an extent by listening on the long wave of the station for long periods. During the preliminary tests 4,000 meters was the sending wave length. For regular work it is probable that the wave length will be about 6,000 meters.

TESTING AND EXPERIMENTAL WORK.

In laying out the buildings, power leads, etc., the use of the station for testing apparatus and for experimental work in the development of new devices was kept in mind, and the arrangements for this class of work are excellent. The switchboard has sixteen panels of white marble for the handling and distribution of currents, direct and alternating, of various voltages and frequencies. At present but five panels are in use, namely: The 25-cycle distribution, synchronous motor, 100-kw. transmitting generator, 60-cycle lighting, and plug distribution panels. The proposed uses of the other panels are as follows: 5-kw., 500-cycle secondary-station transmitter; 15-kw., D.C., oil-engine set; three D.C., distribution panels; two storage-battery panels; three A.C. panels (60, 120 and 500 cycles), and one laboratory-distribution panel. There are outlets for power leads in six different rooms now used as laboratories or offices, which, from the plug panel, can be supplied with current from other panels of the switchboard. The test plate is furnished with a panel having four switches, connected to the plug panel for handling current to or from apparatus under test on the test plate.

PERSONNEL.

The station is under the direct control of the Superintendent of Radio Service. To his office are attached a line officer as Assistant Superintendent, a Pay Officer, in charge of accounts involved by the opening of certain stations to general public business under the terms of the Berlin Convention of 1906, two civilian clerks and a chief yeoman. In charge of the crew and operation of the station, is a line officer. His principal assistant is a Chief Electrician, who is quartered in

a separate room, over the main laboratory. There are twelve operators of various grades of radio electricians, three of which are on watch at one time. They stand watch in four at three posts, namely: Receiving room, operator's office and transmitter room. All details are interchangeable. The receiving operator and the operator at the telephone switchboard, telegraph instruments and special typewriter are permitted to relieve each other when necessary, the last mentioned acting as general assistant and messenger for the operator on watch. Other members of the crew who stand no night watches except in emergencies or in case of temporary illness, are: One chief electrician, one machinist's mate, 1st class, and one yeoman, 3d class, who is the postmaster of Radio, Virginia, in addition to his duties in the office of the officer-in-charge. Total enlisted force, seventeen. Twenty-one men can be easily quartered in the building, and it is proposed to have men detailed to the station for instruction from time to time. Married operators are not required to live at the station, but comfortable quarters in the neighborhood are scarce. Each man is allowed subsistence at the rate of one dollar per day, and from the mess money are paid the wages of a cook, a laundress and a waiter. The officers attached to the station have the same luncheon as the station crew, for which they reimburse the mess monthly. All hands find the duty very agreeable, and the only discipline necessary is the occasional prompt detachment of an operator whose actions are considered unsatisfactory.

FORECAST.

The development of the usefulness of the station as a means of direct communication with various points along the coast, with ships of the Navy at sea, with other high-power stations to be built on the Canal and on the California coast, and with War Department stations in the interior of the country; and its use as a well equipped experimental station, will be a subject of increasing interest to, and will reflect great credit on, the Naval Service.

PROPELLING MACHINERY OF U. S. BATTLESHIPS.

By Ernest H. B. Anderson, Associate.

My object in writing this article is to reply to various criticisms which have been made against the adoption of turbine-propelling machinery in the battleships of this Navy, and my remarks will specially refer to those of the Parsons reaction type.

Further, it is my purpose to put forward additional arguments in favor of the retention of this type of rotative engine in these large war ships.

Capt. C. W. Dyson, U. S. N., has written exceptionally clever and valuable papers, which were read to the members of the Engineers' Club in Philadelphia and to the members of the Society of Naval Architects and Marine Engineers in New York, in which he showed that the performance of the battleship *Delaware* had not been improved upon by the turbine machinery installations of the later ships of this class.

This is open to question, and it seems to me that the only way in which really accurate comparisons can be made between such ships is to carry out coal-consumption sea trials of long duration, with the ships running side by side and as far as possible under similar conditions. Capt. Dyson bases his claims largely on the water-consumption data recorded during the builders' trials, and great caution should be exercised in using this data, for the chief reason that the *Delaware* is the only reciprocating-engine battleship on which water-measurement trials have been carried out, and the results are so favorable as to make one believe it might not be possible to equal them in other vessels having the same type of machinery.

When turbine machinery was first proposed it was found that there were many naval engineers who fully believed that they had not reached the limit in the design of the reciprocating engine, and the machinery of *Delaware* has many radical changes, compared with the installations of the earlier ships, with the result that the performance both as regards upkeep and fuel economy has been exceptionally good.

The conditions laid down by the Navy Department were such that it made the problem of designing a turbine installation one of very great difficulty.

The speed required on a full-power trial was twenty-one knots. A very large cruising radius at ten knots was absolutely essential, and the difficulties were still further increased by the fact that the length of engine room was limited in the early ships of *Dreadnought* class, so that installations having the regular four-shaft Parsons turbines were out of the question.

As this type of vessel increased in size longer engine rooms became permissible, and at the beginning of 1909 the battleships *Florida* and *Utah* were laid down, having propelling machinery installations of Parsons reaction turbines.

These two ships have been in commission about eighteen months and have achieved remarkable success. They can be compared with the *Delaware* on approximately an equal basis.

Careful water and coal-consumption trials were made on the preliminary acceptance runs, but unfortunately the results are not entirely satisfactory to make accurate comparisons.

WATER CONSUMPTION TRIALS.

In the case of *Delaware* and *Florida* the steam consumption of the main engines and that of the auxiliary machinery was measured separately, whereas on the trials of *Utah* the steam consumption of main engines and auxiliary machinery were measured together.

The recorded figures are as follows:

	Speed, in knots.	Water consumption, all auxiliary machinery. Pounds per hour.	Total water consumption. Pounds per hour.
Four hours at full speed:			
Delaware, .	21.56	40,557	422,931
Florida, . .	22.08	67,352	560,780
Utah,* . . .	21.04	62,400	406,427
Twenty-four hours at nineteen knots:			
Delaware, .	19.217	30,512	243,810
Florida, . .	19.19	56,382	308,051
Utah,* . . .	19.225	47,400	262,398
Twenty-four hours at twelve knots:			
Delaware, .	12.24	23,457	83,462
Florida, . .	12.08	41,843	116,386
Utah,* . . .	12.018	29,500	98,498
Wyoming, .	12.266	42,200	...

* The figures of auxiliary steam consumption given for *Utah* are estimated, but are obtained by deducting the estimated steam consumption of the turbines, based on the belt pressures from the total water-consumption records.

A careful study of these figures will convince one that any comparison between the boiler performance of these ships, based on the recorded water measurements, is practically valueless, due to the large differences in measurement of the auxiliary-machinery steam consumption.

In other words, the data tends to show that similar conditions did not exist during the trials of these ships.

COAL CONSUMPTION TRIALS.

For the full-speed trial the coal was put into bags, each bag having the same amount, and during the run the number of bags used was counted. On the twenty-four hour trials the bunkers were "striped," and by leveling off the bunkers, before and after the trial, fairly accurate measurements were obtained.

The recorded data is as follows:

	Speed, in knots.	Tons of coal per 24 hours.
Four hours at full speed:		
Delaware,	21.56	578.0
Florida,	22.08	713.0
Utah,	21.04	468.0
Twenty-four hours at nineteen knots:		
Delaware,	19.217	319.20
Florida,	19.19	372.0
Utah,	19.225	283.0
Twenty-four hours at twelve knots:		
Delaware,	12.24	112.0
Florida,	12.08	117.0
Utah,	12.018	118.75

Plate A shows curves of coal consumption per twenty-four hours in terms of speed in knots for *Delaware* and *Utah*.

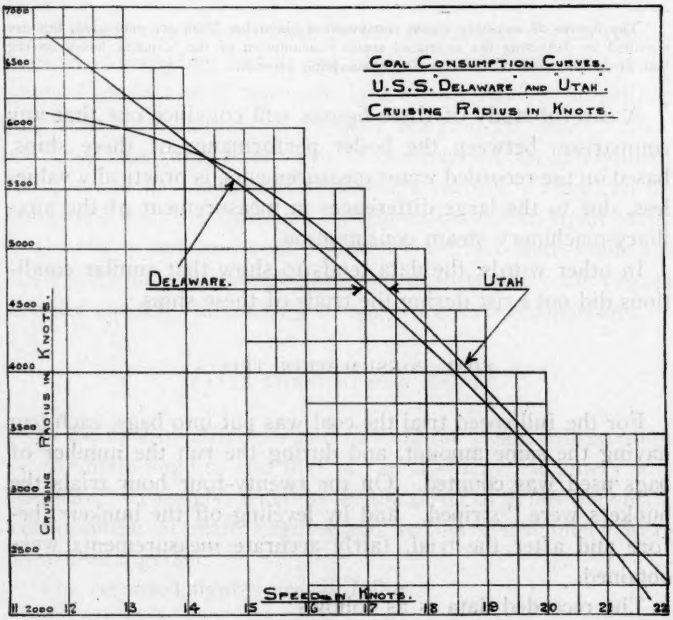


PLATE A.

In addition, I have plotted to "dotted lines" a curve which represents the coal consumption of *Utah* in commission.

Unfortunately, very little data has been published regarding the coal consumption of either *Delaware* or *Utah*, since these ships were put into commission.

The coal-consumption records of *Delaware* which Lieutenant Commander H. B. Price, U. S. N., published in his article giving an account of the run of this ship to Valparaiso and home, show that the preliminary acceptance-trial measurements at twelve knots is practically correct, and the conditions under which this trip was made were very favorable for economical steaming.

Run.	Distance, in miles.	Average speed.	Tons of coal.	Tons coal per 24 hours.
To Rio de Janeiro, . . .	4,918	12.92	1,922	121.40
To Valparaiso, ...	3,832	11.18	1,293	90.53
Home:				
To Rio de Janeiro, . . .	4,012	12.82	1,493	114.50
To Boston, ...	4,793	12.50	1,956	122.42

Unfortunately, Lieutenant Commander Price did not complete his interesting article and state the coal consumed on the twenty-four hour full-speed trial which took place immediately following this trip.*

In the case of *Utah*, the only additional data available is the amount recorded during the final acceptance trial which took place in February, 1912.

In view of having no better data and assuming that the curves are approximately correct, it will be seen that they cross at 14.35 knots; below this speed *Delaware* is the more economical; above, *Utah*.

At 12 knots, *Delaware* is 9¼ per cent. more economical than *Utah*.

At 19 knots *Utah* is 3½ per cent. more economical than *Delaware*.

At 21 knots *Utah* is 7½ per cent. more economical than *Delaware*.

* See JOURNAL AMERICAN SOCIETY NAVAL ENGINEERS, No. 2, Volume 23.

At 21.50 knots *Utah* is 12 per cent. more economical than *Delaware.*

Further, it should be borne in mind that *Utah* is about 2,000 tons greater displacement than *Delaware.*

On considering both these ships on an equal basis of effective horsepower with all appendages, *Delaware* at 21 knots will correspond to 20.82 knots for *Utah;* in which case, *Utah* is 12½ per cent. more economical.

Plate B shows the cruising radius in knots at various speeds, having a bunker capacity of 2,500 tons.

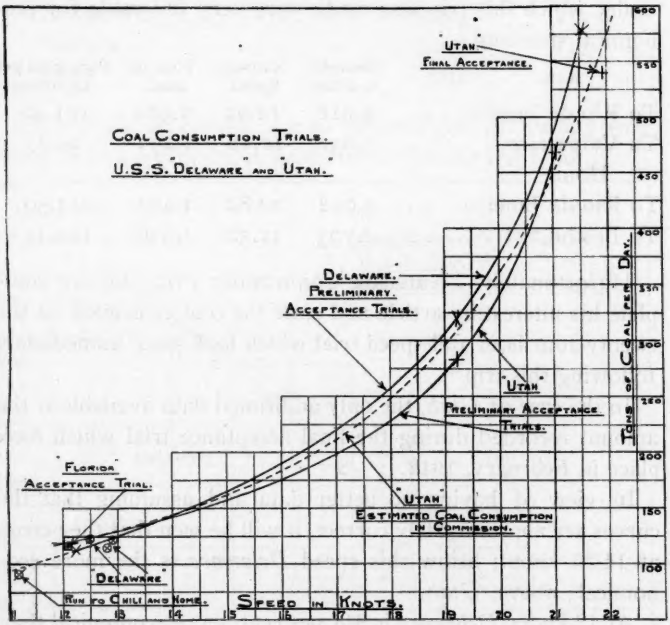


PLATE B.

I have purposely omitted plotting the coal-consumption records of the *Florida,* for the reason that the 19-knot and the four-hour full-speed runs are not directly comparable; but in the case of the 12-knot run, the trial conditions compared with *Utah* very closely.

On the full-speed run of this ship every effort was made to obtain speed, and on the 19-knot trial, the I.P. cruising-turbine combination had to be thrown out, and the trial was run for the last eighteen hours using the main H.P. turbines. This was due to the thrust collars of starboard L.P. turbine rubbing down and reducing the dummy clearance to .004 inch, at which it was considered unsafe to run.

(Note by Editor.—Not being at liberty to publish actual service results, the relative coal consumptions, at different speeds, of the *Delaware* and *Utah* have been plotted and are as shown on Plate E.)

(Speed-coal consumption curves were plotted, from the records on file at the Navy Department and cover all reported runs since the vessels were placed in commission. From these curves, the relative coal consumptions were obtained, and the curves plotted, the *Delaware's* consumption being assumed as 100 per cent.)

PROPELLING—MACHINERY WEIGHTS.

Dealing with the question of weights, the finished weights of the propelling machinery of *Delaware* and *Utah* show that they are about alike.

Delaware ..... 654.50 tons.
Utah ..... 659.00 tons.

The items included in the two cases are as follows:

Delaware.

Main engines and lagging.
Throttle valves and fittings.
Forced-lubrication casings on engines, pipes and tanks.
Exhaust pipes to condensers.
2 condensers, each 11,788 square feet C. S.
All shafting, spring bearings and stern-tube bushes.
Propellers and nuts.
Air and circulating pumps.

Utah.

Turbines and lagging.
Turbine-regulating valves and pipes, all valves and pipes between turbines.
Forced lubrication system, tanks and coolers.
Exhaust bends to condensers.
2 condensers, each 15,225 square feet C. S. each.
All shafting, spring bearings and stern-tube bushes.
Propellers and nuts.
Air and circulating pumps.
Vacuum augmenters.

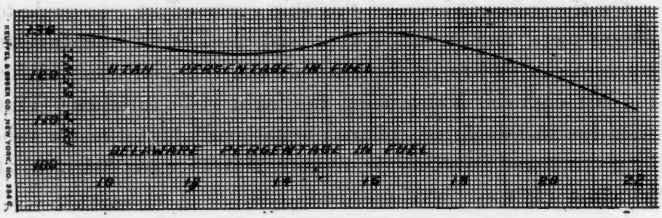


PLATE E.

The total engine-room weights of these two ships are not comparable on an equal basis, for as this class of ship increased in size additional fittings were added; for instance, magazine-cooling and refrigeration machinery has been largely increased, which means more machinery weights.

Further, note that the cooling surface of the condensers in *Delaware* appears to be small, and it is much under the regular requirements of U. S. naval vessels.

(Note by Editor.—The cooling surface is ample as proven by the vacuum obtained on the full-power trials; it being better than that obtained on any reciprocating-engine ship recently tried.)

	Total cooling surface main condensers. Square feet.	Cooling surface. Horsepower.
Michigan, 16,500 I.H.P., . .	19,000	1.15
Delaware, 25,000 I.H.P., . .	23,576	.94
Utah, 28,000 S.H.P., ...	30,450	1.09

The probable explanation may be for the reason that the engine rooms were not large enough to install the standard size of condenser.

ENGINE-ROOM SPACES.

Dealing with the question of engine-room floor spaces, the following figures are of interest, and show that the space required for a four-shaft turbine installation and twin-screw reciprocating engines are about the same:

Ship.	Contract speed, in knots.	I.H.P. reciprocating, S.H.P. turbine.	Displacement, in tons.	Type of machinery.	Engine-room. Length, feet.	Engine-room. Breadth, feet.	Total area, in sq. ft.
Michigan..	18.50	16,500	16,000	Reciprocating.	44	50	2,220
Delaware..	21	25,000	20,000	Reciprocating.	44	50.50	2,222
Utah.....	20.75	28,000	21,825	Parsons turbine.	60	51	3,060
Wyoming.	20.50	28,000	26,000	Parsons turbine.	60	52.50	3,150
Texas.....	21	31,000	27,000	Reciprocating.	60	53.50	3,210
Oklahoma.	20.50	24,800	27,500	Reciprocating.	60	58	3,480

(Note by Editor.—When the designs for the *Texas* and *Oklahoma* were prepared, sufficient engine-room space was provided for turbine installation in case it should be decided to install turbine-driven machinery.)

In the latest design the area of the engine-room floor space has been still further increased, and the arrangement of the proposed reciprocating engines is on the lines of the sketch.

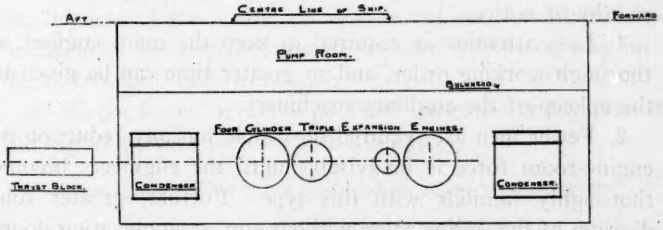


PLATE C.

Plate C.—Such an engine room with its great length is best suited to the requirements of the reciprocating-engine designers, but in the case of a turbine installation additional width is required, which allows for the introduction of large slow-running turbo-rotors.

Plate D shows a sketch of the engine-room arrangement for a four-shaft Parsons reaction-turbine installation, one designed for the same conditions as the foregoing twin-screw reciprocating-engine installation.

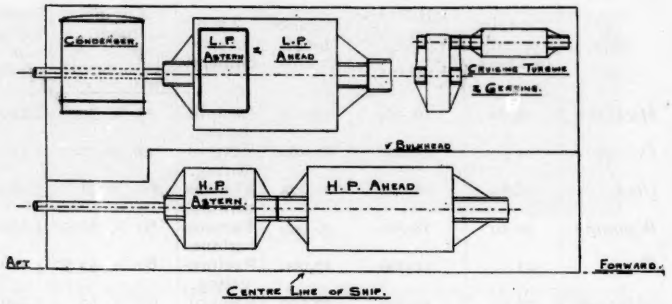


PLATE D.

POINTS OF SUPERIORITY OF THE REACTION TYPE OF TURBINE MACHINERY COMPARED WITH RECIPROCATING ENGINES.

Some of the claims originally made in favor of turbine machinery do not now exist, for the reason, already explained, that the reciprocating-engine designers have greatly improved upon the design of this type, but the following points are worthy of notice.

1. Less attention is required to keep the main engines in thorough working order, and so greater time can be given to the upkeep of the auxiliary machinery.

2. Fewer men are required on watch, but any reduction of engine-room force is inadvisable until the engineers become thoroughly familiar with this type. Further, greater subdivision of the engine room without any communicating doors will, however, probably eliminate this feature. In the case of the three-shaft reaction-turbine destroyers this claim has been proved conclusively.

3. Battleships having Parsons reaction turbines have shown themselves to be absolutely free from vibration at all speeds.

4. With turbine installations a considerable saving in lubricating oil is effected at all powers.

5. Greater cleanliness of engine room exists under moderate and full-speed conditions.

6. Turbine engines have the great tactical advantage of be-

ing installed well under the load-water line and entirely below the protective deck; whereas in a reciprocating-engine-driven ship each hatch extends over the full length of the main engines. In addition, the cylinder covers project through the protective deck, so that it has to be broken and fitted with an armored hood, standing about four feet high.

(Note by Editor.—The cylinder covers do not project through the protective deck on any ship built or building, but on one proposed design they do project through *fourteen inches.*)

7. Turbine machinery of the reaction type with its very rugged construction is capable of being overloaded for long periods, absolutely without any danger of mishap. The scout *Chester* and the three-shaft destroyers have conclusively proved this claim.

8. The best results with the reaction type of turbine are obtained with moderate steam pressures; whereas high-pressure superheated steam is essential for maximum economy with the latest reciprocating-engine designs. Further, owing to the dryness of the steam, oil is essential for the internal lubrication of the engines; sooner or later it finds its way into the boilers and leads to trouble.

9. Water losses or make-up feed are considerably less at the higher powers with turbine machinery.

(Note by Editor.—This is not sustained by actual service reports.)

10. All shafting troubles are eliminated. This is the bugbear of the reciprocating engine; ship after ship reports "shafting troubles."

11. The power transmitted to the hull is equally distributed over four shafts, which means that the machinery has a greater margin of safety and the vessel has a much smaller chance of being put out of action.

12. Finally, the engineers and machinists who operate this type of rotative engine stand by the reaction turbine, and it is to these men that one should go and hear their views on this question.

DISADVANTAGES OF TURBINE INSTALLATIONS IN BATTLESHIPS, AND PROPOSED REMEDIES.

1. *An increase of fuel consumption at 10 and 12 knots, compared with reciprocating-engine installations.*—This condition can be remedied by installing, in place of the direct-driven cruising turbines, geared cruising turbines, which will be used in conjunction with the main turbines at low powers. At full power they will be disconnected or allowed to run idly. In such cases better results can be attained than with the latest twin-screw reciprocating engines.

2. *Poor maneuvering and backing qualities.*—This difficulty can be overcome by allowing greater engine-room spaces, which will allow for the introduction of large, slow-running rotors and propeller wheels of much greater diameter.

3. *Rotor corrosion* simply means neglect. This is overcome by careful supervision down in the engine room. Further, the interior of all battleship turbines are easily accessible for regular examination.

(Note by Editor.—This is a question of "degree of neglect." Corrosion can be prevented, but how much "careful supervision" is required to prevent it?)

4. *Blade erosion* does not exist or take place in the reaction type of turbine, for the reason that the steam velocities are comparatively low.

5. *Blade strips.*—It is exceptional to have blading troubles with the main turbines, and in most instances they have occurred immediately following on an opening up of the turbines for regular periodical examination.

THE INFLUENCE OF THE SHIP'S LINES UPON THE PERFORMANCE OF THE ENGINES.

In all the published accounts dealing with this question as to the best type of propelling engine very little has been said about the hulls of the vessels in which the machinery is placed, and it would seem that a large share of the success

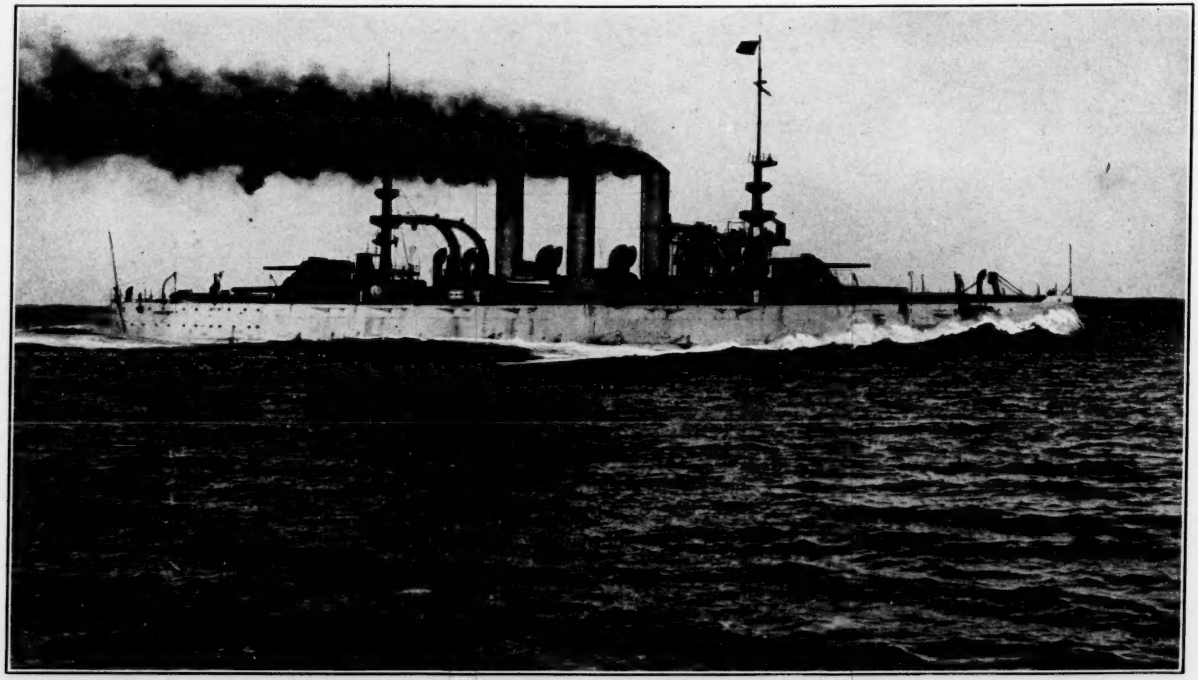


Photo. by STEBBINS, Boston.

PLATE E.—U. S. S. "GEORGIA."

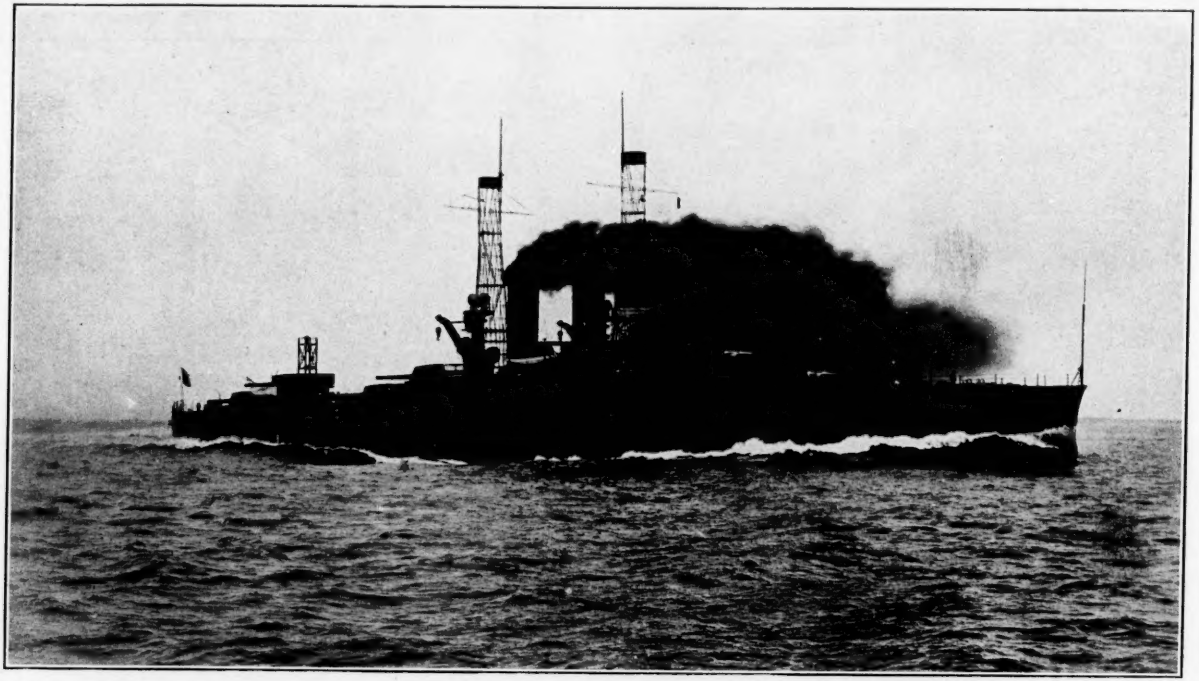


Photo. by STEBBINS, Boston.

PLATE F.—U. S. S. "ARKANSAS."

in the machinery installations has been due to the improved form of the under-water lines in the ships of the *Dreadnought* type.

On the preliminary acceptance trials the engineers found that the vessels were fulfilling the contract requirements, both as regards speed and horsepower, well within the designed figures; whereas it had been confidently anticipated at the time the engine details were being laid out that they would require to develop from eight to ten per cent. more power than the estimated figures.

To illustrate my meaning, the following photo-prints are of interest, showing U. S. S. *Georgia* and *Arkansas* at full speed. The preliminary acceptance trials of these vessels took place in 1906 and 1912 respectively.

Georgia, 24,600 I.H.P.; speed, 19.26 knots; displacement, 15,000 tons.

Arkansas, 28,530 S.H.P.; speed, 21.05 knots; displacement, 25,550 tons.

Note the contrast between the disturbance at the bow in the two cases and compare the wave formation along the side of each ship.

Again, the maximum speed on any full-power run attainable with *Delaware* is about 21.50 knots, or .50 knot in excess of the contract requirements; whereas in the case of *Florida* and *Utah* the contract speed of 20.75 knots has readily been exceeded by one knot. This will apply equally as well to the later ships *Arkansas* and *Wyoming,* which have turbine machinery of the same type.

CONCLUSIONS.

In a battleship of 25,000 I.H.P. and twenty to twenty-one knots maximum speed, one required to steam for long distances at low cruising speeds and burning coal fuel under the boilers, then I believe the reciprocating engine is in its right place, for the good reason that the machinery can be placed in comparatively small engine rooms; whereas direct-driven

turbine installations will require much longer engines to attain the same results.

But the answer to this will be found in the introduction of geared turbines.

Very great strides are being made in this direction; over 150,000 horsepower of Parsons geared turbine machinery is built and under construction. By this means great economy will result both at full power and at low cruising powers, and within a very short time an installation of such a type will not be considered in the light of an experiment.

Again, the *Dreadnought* class of ship has increased nearly fifty per cent. in size since *Delaware* was designed; oil fuel has taken the place of coal. I am firmly of the opinion that turbine machinery is the only practical solution for such a problem.

In the destroyer classes it has been proved conclusively that turbine machinery and oil fuel are at the present time the "last word" in the propulsion of such vessels, and this will be found to be the case in the large war vessels of U. S. Navy.

(Note by Editor.—In the first paragraph of "Conclusions" Mr. Anderson seems to have reached a conclusion adverse to the object of the paper and agrees with Captain C. W. Dyson, U. S. N., who stated as follows in his paper "Engineering Progress in the U. S. Navy," read before the Society of Naval Architects and Marine Engineers, in New York, November 21st and 22d, 1912:

"While the reciprocating engine has a decided advantage in the features of weight and space required, under present conditions these advantages would disappear should the necessary power to be developed be increased considerably above what is now asked for, and the advantage would rest with the turbine. Should such an increase of power be called for in future designs, or should the ordinary cruising speed be made considerably higher than now used, the Navy Department would undoubtedly abandon the reciprocating engine and adopt one of its rotary rivals for the propulsion of its capital ships.")

TURBINE-DRIVEN FORCED-DRAFT FANS.*

By Henry F. Schmidt.

The blowers on which comparative tests were run are, presumably, the same as those which have been installed in various destroyers, the Government specifications calling for the delivery of 23,000 cubic feet per minute against five inches of water pressure.

As may be observed from the sketch on page 1168, the blowers as tested by Mr. London, were inclosed in a test house $7 \times 7 \times 7$ feet, and the intake of the blower extended approximately 6 inches above the top of the house and was 31½ inches in diameter. The volume of air delivered by the blowers was measured by a Pitot tube inserted in the intake 31¼ inches, or approximately one diameter below the entrance. There was one outlet, 14 inches in diameter, which could be throttled to vary the amount of air delivered, and one nozzle, 12 inches in diameter, at the outlet, with a 14-inch diameter inlet. The pressure in the test house was measured at two points, which was a wise precaution, as the air discharged from the blower forms eddies, and the two gages, located at different positions, would undoubtedly give a better average.

In all the treatises on hydraulics and the various experiments which have been made on the flow of air through orifices in flat plates, it has been found from tests (as well as from the theory of flow) that the coefficient of flow for such orifices without rounded entrances is about .625 of the theoretical flow.

* Discussion of "Comparative Tests of Three Types of Turbine-Driven Forced-Draft Fans," by W. J. A. London, in the "Journal of The American Society of Naval Engineers," Vol. XXIV, No. 4.

Since the inlet pipe to the blowers was not fitted with a rounded entrance or suitable series of conical approaches, the coefficient of flow through the inlet to the intake pipe would be approximately the same as the flow through a hole in a thin plate; *i. e.*, .625 of the theoretical flow; and, owing to the fact that the intake pipe extended somewhat above the level of the roof of the test house, the coefficient could not be expected to be as high as that of a hole in a thin plate, for there is a certain amount of double contraction due to the air making a double turn of about 180 degrees in entering the pipe. The coefficient would be further reduced because of the injector action of the two discharge outlets, which are in very close proximity to the inlet, and it may be assumed from the arrangement that the observers were stationed on the roof of the test house, and the obstruction afforded by their presence would also tend to reduce the flow to the intake. The

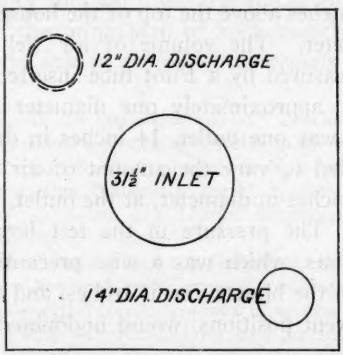


FIG. 14.

sketch hereto attached, made from the description of the test house, shows the location of the discharge openings in reference to the intake, from which the seriousness of the injector action spoken of will be readily appreciated.

Mr. London has assumed a coefficient of flow of .98 and calculated the volume of air entering the blowers as being equal to .98 of the cross-sectional area of the inlet, namely,

5.41 square feet into the velocity measured by the Pitot tube. While there is always a question as to the accuracy of Pitot-tube readings taken in this manner, nevertheless, assuming the readings in this case to be perfectly accurate, the question of the contraction of the stream lines is not eliminated, for the maximum contraction occurs approximately one diameter from the orifice in a thin plate. This is the point at which Mr. London took his readings, and though the effective area of the stream issuing from an orifice in a thin plate is only .625 of the area of the orifice, the velocity acquired by the jet for small pressures is essentially equal to the theoretical.

As there are apparently only the two orifices for the discharge of air from the test house, we have assumed a coefficient of flow of .625 for the 14-inch orifice, which we will assume to be wide open, and a coefficient of .90 for the conical nozzle. During the tests a pressure of five inches of water was maintained in the test house, and, calculating the velocity of air due to this pressure difference, we find that the 14-inch orifice can pass about 6,000 cubic feet per minute, and the 12-inch orifice 6,400 feet per minute, giving a total of 12,400 feet per minute as the possible discharge from the test house, neglecting leakage.

From tests of a similar nature carried out in a test house of twice the external area, it was found that the leakage amounted to between 4,000 to 5,000 cubic feet per minute, so that for a test house of this size we may assume a leakage of not more than 2,000 or 3,000 cubic feet per minute. Adding a maximum of 4,000 for leakage to the above 12,400 which can pass through the discharge nozzles, we get a total of 16,400 cubic feet per minute.

Now the maximum volume recorded during the tests by Mr. London (Test "B," Table 3, page 1176) is 26,020 cubic feet. If this volume is corrected from the coefficient of .98 to .625, it gives 16,600 cubic feet per minute, which checks very closely with the discharge volume of 16,400 cubic feet.

There can be no reasonable doubt but that the volumes as recorded are approximately 37 per cent. greater than the actual

volume handled, while, of course, the air horsepower is a similar per cent. too large, and the water rate per air horsepower is approximately 37 per cent. too low.

A WESTINGHOUSE TURBINE-DRIVEN BLOWER.

The following is a description of a turbine-driven forced-draft fan for the U. S. S. *Barry* and the tests which were run on it at the shops of The Westinghouse Machine Company at East Pittsburgh.

The blower is of the shallow-vane type, with single inlet, and having the blower wheel mounted directly on the shaft of the turbine. There are but two bearings supplied by forced lubrication. The general appearance of the blower, as seen from the throttle-valve side of the turbine, is shown in Fig. 1. A rear view is shown in Fig. 2, and one looking down from above, in Fig. 3. Fig. 4 shows the blower rotor and Fig. 5 the intake cones and casing, while Fig. 9 shows a sectional view of the deflector cones and other details of the blower casing.

The object of the deflector cones is to lead the air into the blower quietly and in planes at right angles to the shaft, thus increasing the capacity and reducing the amount of noise. These cones are stationary, being riveted to the intake ring, a steel casting, which, in turn, is riveted into the blower part of the cowl and serves to carry the blower casing.

The turbine is of the three-velocity-drop impulse type, employing but a single row of blades. Fig. 6 is a developed section of the center line of blades, "A" being the high-pressure nozzle, in which the steam is expanded to the exhaust pressure at which it impinges on the blades. It is redirected to the same row of blades in the proper direction by the reversing chambers "B" and "C," and thence to the exhaust.

The turbine is equipped with an automatic-stop throttle valve of the piston, balanced-disc type, which supplies both primary and secondary nozzles, so that the turbine will shut down if the automatic stop ("A," Fig. 1) is tripped, regard-

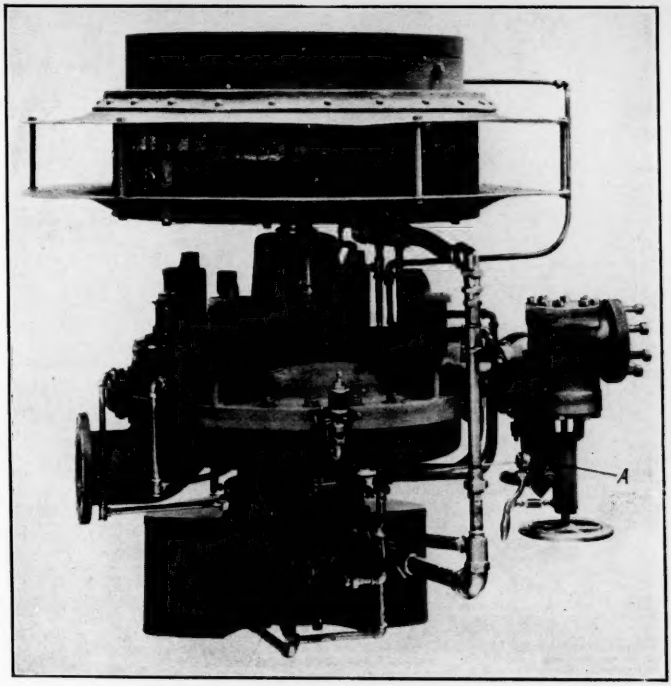


FIG. 1.

FIG. 2.

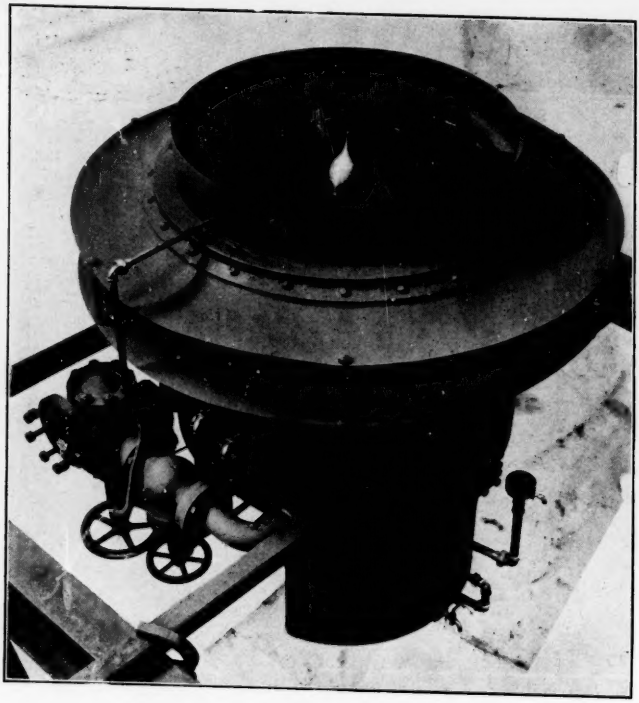


FIG. 3.

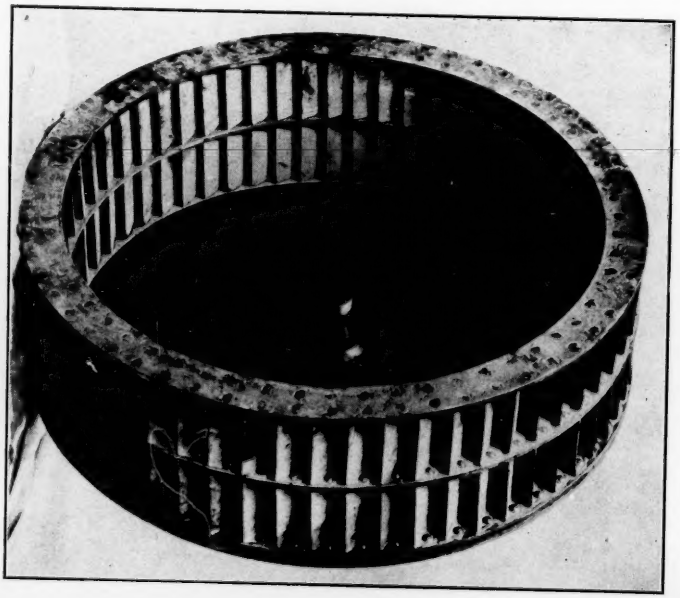


FIG. 4.

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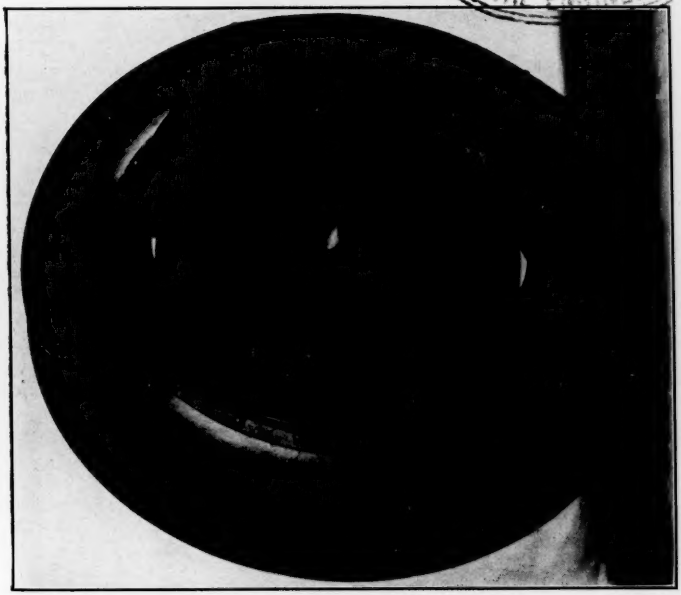


FIG. 5.

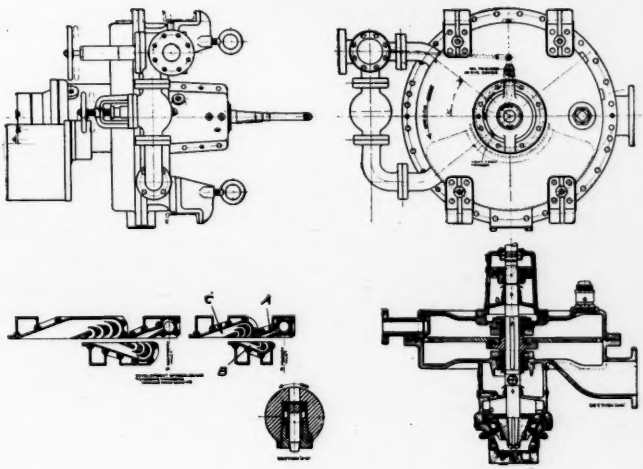


FIG. 6.

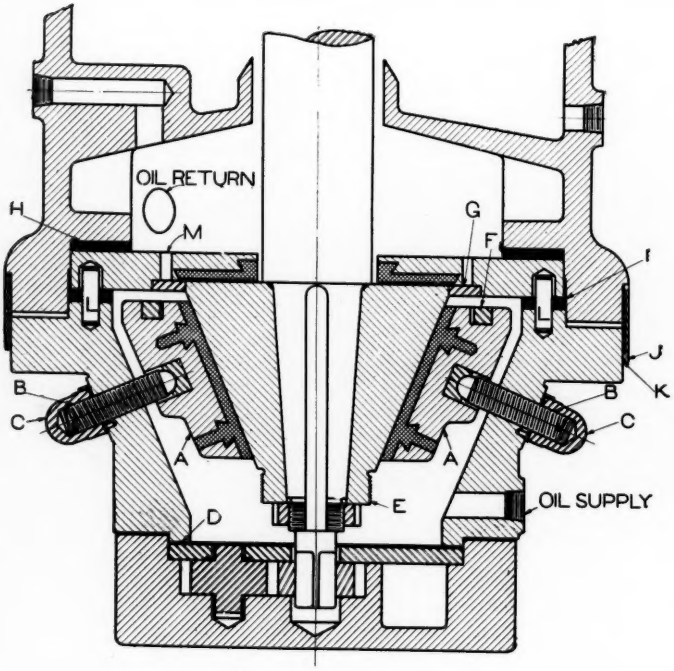


FIG. 7.

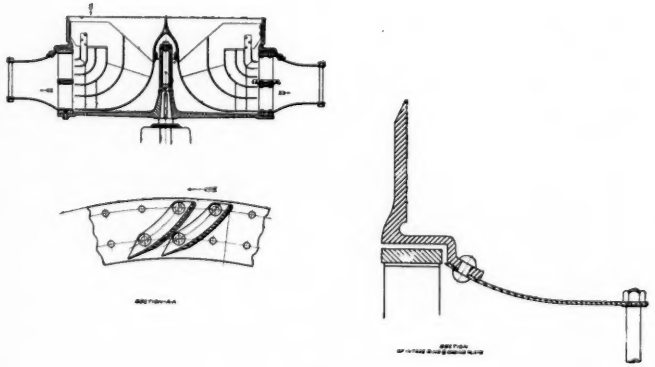


FIG. 9.

less of whether the primary alone or both primary and secondary are in operation.

The weight of the rotating element of the turbine is carried on a segmental conical thrust bearing, shown in the assembly, Fig. 6, and in detail in Fig. 7. A steel cone, " E," Fig. 7, is mounted on the lower end of the shaft and rotates in a babbitted bearing consisting of eight segments. In order to prevent the possibility of the blower spindle lifting, due to the air pressure on the under side of the blower rotor when the ship is rolling heavily, an upper retaining bearing is provided, which normally has its position about .010 inch above the upper surface of the cone bearing.

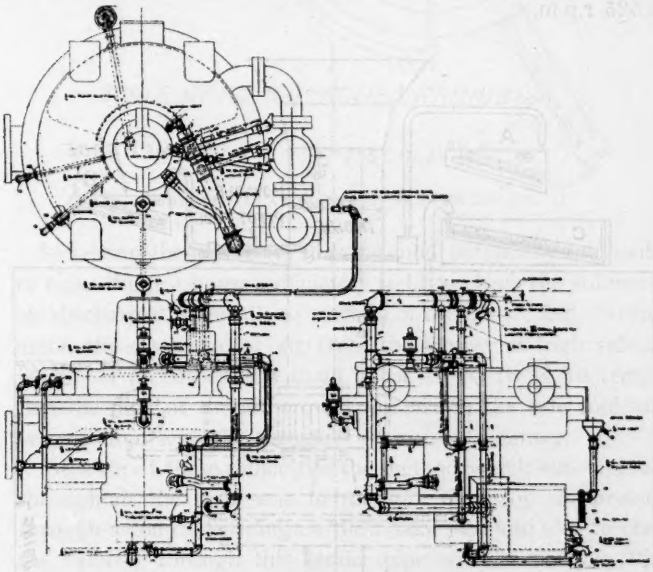


FIG. 8.—OIL-PIPING ASSEMBLY.

The pump for furnishing the bearings with oil, as shown in the lower part of Fig. 7, consists of a pair of spur gears, one of which is secured to the lower end of the shaft. Since the turbine does not operate at constant speed, but has to work at low speeds as well as high, the pump is made sufficiently

large to supply the upper bearing at speeds as low as 200 r.p.m., which is lower than the blower would ever operate.

As to capacity, the primary nozzle of the turbine has been designed so that the blower is capable of delivering 25,000 cubic feet of air per minute against a water pressure of 5 inches when the turbine is running at 1,200 r.p.m. and the inlet pressure on the nozzle is 300 pounds absolute. The secondary nozzle is designed to pass approximately twice as much steam as the primary; thus the turbine is capable of developing about 2¾ times its normal rating. This will enable the blower to operate at approximately 50,000 cubic feet per minute against five inches water when making about 1,500 to 1,525 r.p.m.

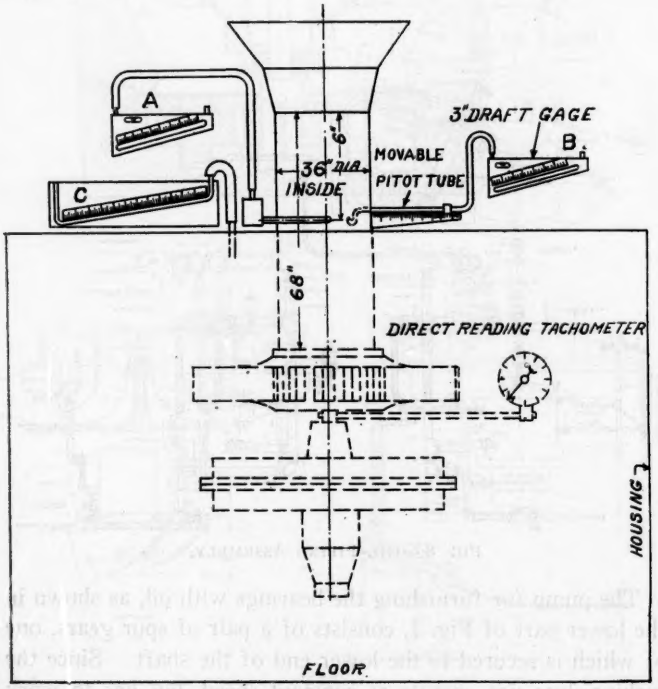


FIG. 11.

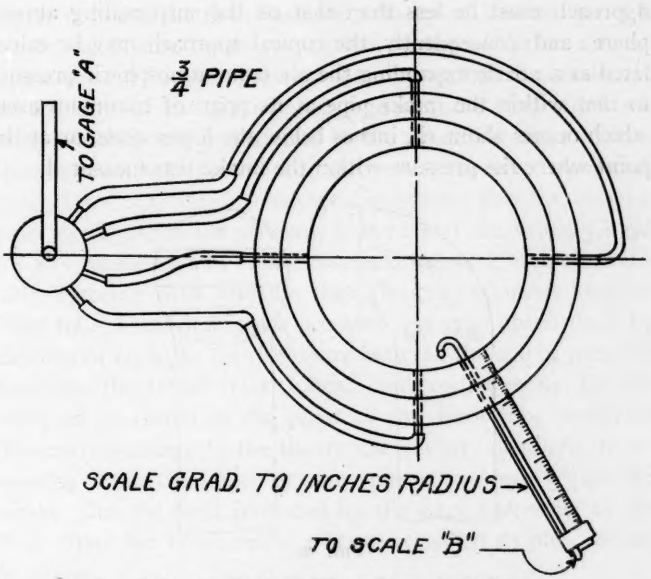


FIG. 12.—PLAN VIEW OF BLOWER INLET.

In testing these blowers it was found practically impossible to make the test house sufficiently tight to check the volume of air discharged by means of orifices in the house, and, furthermore, the discharge of air from the blower at high velocity would set up eddies in a small house 10 × 10 × 10 feet, so that the flow of the air from an orifice in the side could not be measured with the necessary degree of accuracy.

Because of these difficulties the method which was followed throughout the tests was to measure the drop of pressure through a conical opening on the intake pipe and also to check the velocity through this intake pipe with a movable Pitot tube, by means of which the stream could be searched across more than half the diameter of the pipe.

The arrangement of the intake pipe and conical approach and gage connections is shown in Fig. 11, and a plan view in Fig. 12. It will be observed that since the air must flow into the intake, the pressure at the smallest point of the conical

approach must be less than that of the surrounding atmosphere; and, consequently, the conical approach may be calculated as a nozzle expanding the air from atmospheric pressure to that within the intake pipe at its point of minimum area, which occurs about six inches below the lower cone, or at the point where the pressure within the intake was measured.

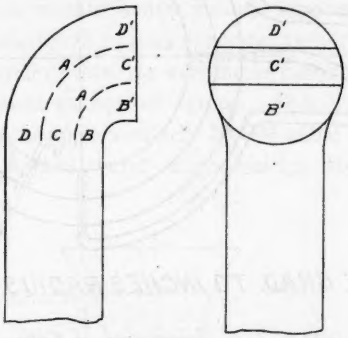


FIG. 10.

Fig. 10 shows partitions or guides in the cowls, to insure the air reaching the fan in parallel streams and to prevent eddy currents due to the sudden change in direction.

It will be noted from Figs. 11 and 12 that the pressure in the inlet was measured at four points symmetrically located about the periphery and averaged by means of a suitable reservoir which, in turn, was connected to a 3-inch Schaeffer & Budenberg differential draft gage graduated to read .02 inch water pressure.

The Pitot tube—the location of which is also shown in Figs. 11 and 12—was not used in the method ordinarily employed, in that the gage was not connected to the intake pipe, but was left open to the atmosphere at one end and connected to the Pitot tube at the other. The end of the Pitot tube within the intake pipe was pointed directly upwards, so as to measure the velocity head of the air entering the intake.

Now, since the Pitot tube measured the velocity head and one end of the gage connected thereto was open to atmos-

phere, it is evident that since the velocity of the air through the intake is due to the expansion of the air from atmospheric pressure to the pressure existing within the intake, if the velocity of the air entering equalled the theoretical velocity which would be acquired in the expansion from atmospheric pressure to that within the intake, the gage connected to the Pitot tube should read zero, indicating that the velocity head was equal to the pressure head; but if the velocity head for any reason should be less than the pressure head theoretically agreeing with velocity, then the gage connected to the Pitot tube would indicate a pressure less than atmosphere by an amount equal to the difference between the actual pressure head and the actual velocity head, and, consequently, the velocity as measured at the point of the Pitot tube would be that corresponding to the theoretical velocity acquired in expanding from the upper or atmospheric pressure within the intake, plus the head indicated by the gage connected to the Pitot tube, the latter reading being regarded as plus instead of minus.

It was found from the test that the difference in velocity between the theoretical and the actual was so slight that for all practical purposes, the coefficient of flow of the conical approach, considered as a nozzle, may be considered as unity.

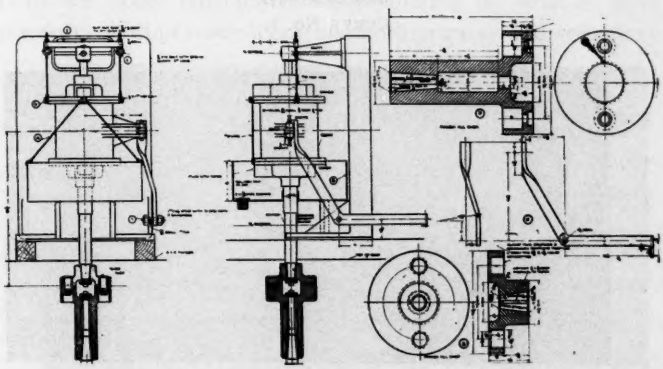


FIG. 13.

Though not shown in Fig. 11, a wet and dry-bulb thermometer was suspended at the intake to the upper cone during the tests, in order to determine the temperature and humidity of the air entering the blower.

The air pressure within the test house corresponding to the stokehold was determined by means of a differential gage.

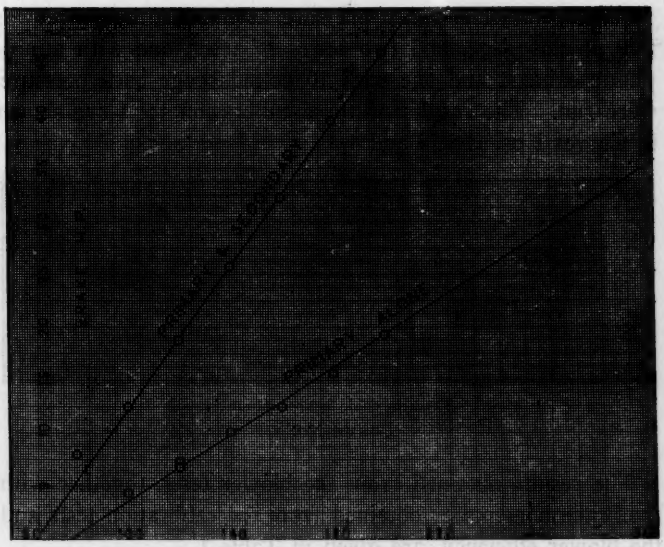
During all the tests on the blower the steam was weighed in steel tanks on platform scales. These tanks were so arranged that the outlet could be observed to insure that there was no leakage from the drain valves.

Brake horsepower.

CURVE NO. 1.

Nozzle pressure, pounds per square inch absolute.

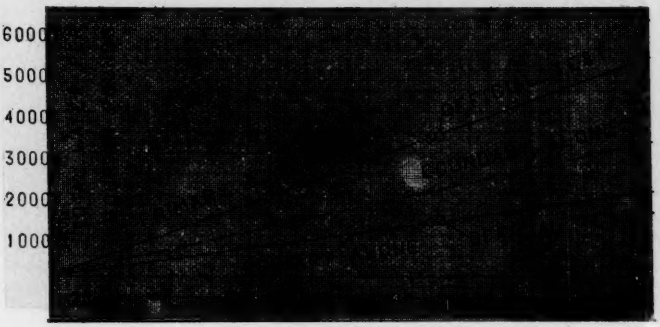
CURVE NO. 2.



Inlet pressure pounds absolute.

CURVE NO. 3.

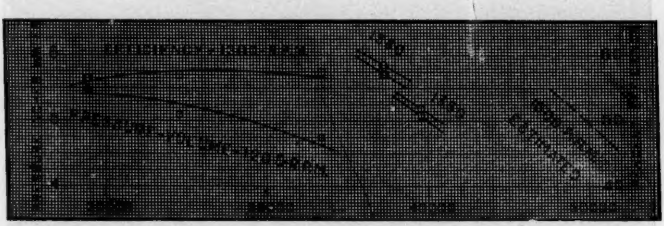
In addition to the tests with the blower the blower wheel was replaced by a water brake of standard design (shown in Fig. 13, which is self-explanatory) and the tests run to determine the brake horsepower corresponding to various inlet pressures with primary alone and both primary and secondary



Absolute inlet pressure, in pounds.

CURVE NO. 4.

valves open. The steam pressure at the throttle valve was 200 pounds gage, and two series of tests, one with atmospheric exhaust and one with 10 pounds gage back pressure, were run. The results of these calibration tests are shown in Curves Nos. 1, 2, 3 and 4.



Volume cubic feet per minute.

CURVE NO. 5.

The results obtained from the blower tests, together with the brake horsepower obtained from the calibration tests and the blower efficiency, are given in Table I.

Curves Nos. 5 and 6 show the relation between the pressure and volume per minute at different speeds, and the relation between the volume in cubic feet per minute and brake horsepower at different speeds, respectively.

Cubic feet per minute.

CURVE NO. 6.

Due to the inability to secure 300 pounds absolute inlet pressure on the nozzles, the contract conditions could not be fulfilled but by projecting the calibration curve to 300 pounds absolute inlet pressure, it will be observed that the turbine is capable of delivering a little over 35 B.H.P. on the primary nozzle alone. In this manner the total water rate can be obtained under the desired conditions.

TABLE I.

Test number.	Boiler pressure.	Primary inlet pres., test gage.	Secondary inlet pressure.	Steam temperature.	Air inlet pres., "water."	Air outlet pres. corr. for gage calibration.	Wet-bulb therm.	Dry-bulb therm.	Speed by tachometer.	Calculated vol. cu. ft. per min.	Air H.P. theoretical, calculated.	B.h.p. from calibrations.	Blower effcy., pr. ct.	Barometer.
1	200.1	152.6	152.8	391.0	1.336	4.76	64.7	73.5	1,206	33,414	24.83	43.2	57.5	29.17
2	200.0	128.6	128.6	389.7	0.729	5.11	66.0	74.0	1,200	24,628	19.76	34.7	57.0	29.20
3	200.0	111.0	111.0	391.9	0.430	5.46	65.0	73.0	1,200	18,971	16.45	29.1	56.5	29.09
4	198.0	187.2	187.8	391.0	1.670	5.85	65.0	74.0	1,370	37,352	34.26	59.9	57.2	29.09
5	197.5	190.5	191.0	391.4	1.870	5.17	67.0	76.0	1,366	39,552	34.00	60.7	56.0	29.09

TRIALS OF U. S. S. *HENLEY*.

By A. Conti, Associate.

The U. S. S. *Henley*, a torpedo-boat destroyer built by the Fore River Shipbuilding Company, differs from her sister ships, the *Perkins, Sterett* and *Walke*, built by the same company, in the motive power, which is a combination of two sets of reciprocating engines and turbines designed for maximum economy at cruising speed.

Like her sister ships she is equipped with four Yarrow boilers of 18,000 square feet total heating surface, burning fuel oil exclusively. Each boiler is supplied with seven mechanical atomizing burners of the Yarrow-Fore River type.

Each fireroom has two vertical Sturtevant blowers, driven by a 27-inch pitch diameter Curtis turbine with a single wheel carrying five rows of moving buckets.

Each fireroom contains, besides the complement of auxiliaries usually found in other vessels of the same class, one Griscom-Spencer vertical multi-coil feed heater of 129 square feet heating surface.

The main machinery has been previously illustrated and described in a " Report of Shop Tests of the Starboard Propelling Unit of the U. S. S. *Henley*," published in the February, 1912, number of this Journal. It is sufficient to recall that the main turbines are of the Curtis marine type of 63-inch pitch diameter, with 18 ahead stages with a total of 42 rows of moving buckets, and two stages for going astern with eight rows of buckets.

Each turbine is designed to develop 5,500 S.H.P. at 585 r.p.m., corresponding to a speed of vessel of about 29½ knots, and to pass 19.5 pounds of live steam per second at a pres-

sure of 250 pounds gage at the turbine steam chest and an absolute vacuum of 27 inches of mercury at the exhaust shell.

Forward of the turbine, and connected to it by means of a jaw clutch, is a 10½-inch by 22-inch by 10-inch vertical, compound, reciprocating engine of the Bellis type, which at 16 knots is intended to develop 400 I.H.P. at about 280 r.p.m. with a steam pressure of 250 pounds gage at the H.P. valve chest and when exhausting slightly over atmospheric pressure into the turbine.

Since, however, the *Henley* ran her official trials at a displacement slightly heavier than the normal and with a set of spare propellers from one of her sister ships, the revolutions and power increased slightly above the original design.

The S.H.P. was measured by Hopkinson-Thring torsionmeters, one on each shaft, both shafts and torsionmeters having been previously calibrated in the shops to obtain the torsional modulus of elasticity of the material and the torsionmeter constants.

The all-purpose steam and oil consumption was measured in calibrated tanks and a complete set of engine and fireroom data was collected by the Trial Board and the constructor's staff.

While not a part of the official trials, the summary of a two-hour trial with the main turbines only, run under the supervision of the Board, is appended for comparison.

U. S. S. "HENLEY."—RESULTS OF OFFICIAL TRIALS, ENGINE-ROOM DATA.

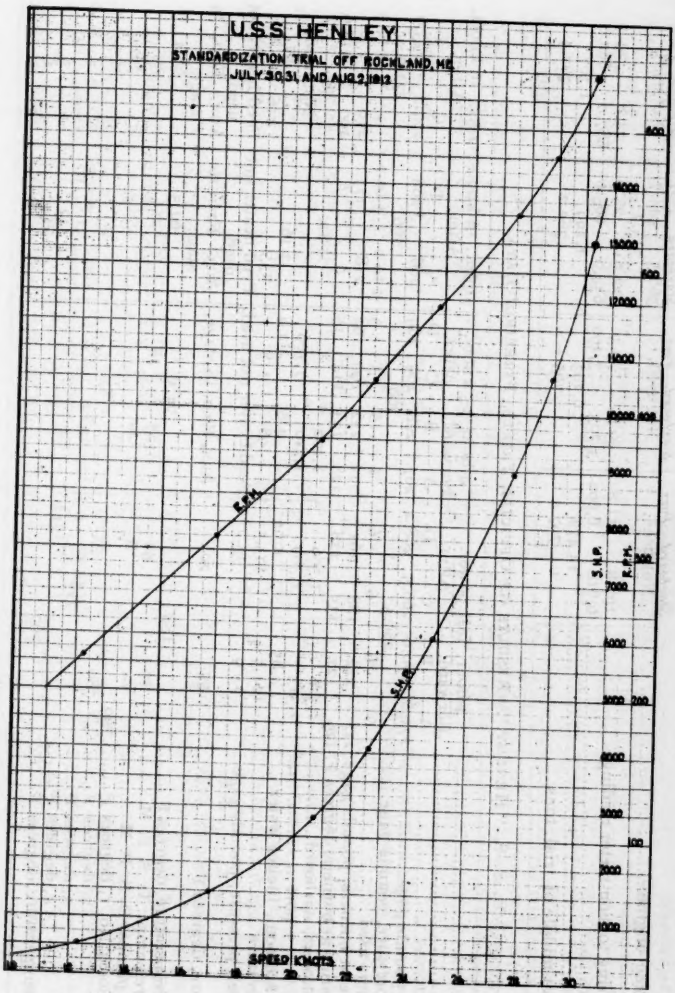
	Sept. 24, 1912.		Sept. 24, 1912.		Oct. 10, 1912.		Sept. 25, 1912.	
Date of trial								
Duration of trial, hours	4		4		10		2	
	Starboard.	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
R.p.m.	645.44	638.26	483.0	475.7	290.92	291.65	291.74	294.02
Average r.p.m.	641.8		479.4		291.28		292.88	
Speed, knots	30.41		25.0		15.97		16.0	
Number of turbine nozzles open	14 to 16		3 Cr. and 5 Reg.		No live steam to turbines.		3 cruising.	
Pressures:								
Main steam, pounds gage	244.8		259.1		263.5		258.4	
Cruising engine, H.P. cyl. valve chest, pounds gage	.....		.....		234.8	227.8	.....	
receiver, pounds gage	.....		.....		55.4	49.8	.....	
exhaust, pounds gage	.....		.....		4.18	5.11	.....	
Turbines, steam chest, pounds absolute	255.1	255.3	250.4	248.0	...	...	190.0	191.0
first stage, pounds absolute	144.0	144.8	72.1	73.0	17.0	14.9	25.5	26.1
fifth stage, pounds absolute	32.0	31.6	16.0	16.3	3.4	3.8	5.4	5.32
exhaust, inches of mercury*	27.06	27.62	27.72	28.0	28.53	28.49	28.42	28.43
Condenser vacuum, top, inches of mercury*	27.61	28.13	27.85	28.2	28.68	28.67	28.48	28.67
Barometer, inches of mercury as read	30.42		30.4		30.12		30.3	
Auxiliary exhaust, pounds gage	17.1		5.4		3.2		4.0	
Oil cooler, pounds gage	31.1		32.0		31.6		24.6	
Main air pumps, steam-chest pressure, pounds gage	147.0		125.0		121.4		.....	
Main feed pumps, steam-chest pressure, pounds gage	233.0		Not used.		Not used.		Not used.	
Temperatures, degrees F.:								
Injection	56.9	56.6	56.9	56.8	54.0	53.9	59.7	58.8
Discharge	88.5	87.9	82.8	83.0	68.0	67.4	76.0	73.2
Dry-air pump suction	80.8	...	71.7	76.0	60.7	61.6	71.0	70.0
Wet-air pump discharge	90.0	91.6	73.3	...	61.7	...	...	70.0
Lubricating oil entering cooler	129.0		116.6		102.8		98.8	
Lubricating oil leaving cooler	98.2		87.3		84.5		77.8	
Revolutions or D. S. P. M.:								
Main air pumps	39.9	37.8	28.0	27.8	33.2	36.3	...	48.0
Main circulating pumps	253.3	250.4	190.0	190.	111.5	111.5	200.	200.0
Main feed pumps	28.6	29.5	Not used.		Not used.		Not used.	
Forced-lubrication pump	17.5		11.0		14.8		8.0	
Oil-cooler circulating pump	40.4		37.7		15.6		44.8	

*Corrected to 30" barometer.

Miscellaneous:	4-hour, full power.	4-hour, 25 knots.	10-hr., 16 knots.	2-hr., 16 knots.
I.H.P. of cruising engine	Starboard. Port. Not used.	Starboard. Port. Not used.	Starboard. Port. 368.5 344.7 713.2	Starboard. Port. Not used.
Hopkinson-Thring torsion-meter readings	107.8 111.8	69.5 70.3	22.91 24.0	24.8 24.4
S.H.P.	6,810 6,662	3,203 3,190	634.0 665.0	687.0 682.0
Total S.H.P.	13,472	6,393	1,299	1,367
Displacement at middle of trial, tons	767.4	765.1	762.2	762.4

U. S. S. "HENLEY."—RESULTS OF OFFICIAL TRIALS, FIREROOM DATA.

Name of trial	4-hour, full power.				4-hour, 25 knots.				10-hr., 16 knots.		2-hr., 16 knots.	
Fireroom	Forward.		After.		Forward.		After.		After.		After.	
Boiler	A	B	C	D	A	B	C	D	C	D	C	D
Boiler pressure, pounds gage	271.6	270.6	266.5	268.4	267	268	269	269	266	266	274.2	273.6
Average boiler pressure, pounds gage	269.3				268				266		273.9	
Number of burners used	6	6	6	6	6	6	3	3	1 to 2	1 to 2	2	2 to 3
Fuel-oil pressure at burners, pounds gage	222	222	188	161	222	222	190	162	218	171	210	130
temperature at burners, degrees F.	129	127	135	128	128	134	114	115	?	?	100	114.6
R.p.m., F. D. blowers, starboard	1,306		1,306		1,202		.....		820		980	
port	1,313		1,309		1,312		1,106		.....		Not used.	
Air pressure in fireroom, inches water	4.85		4.94		4.8		2.8		2.16		2.67	
Fireroom temperature	104.5		115.5		98		118		135		116	
Feed heater, shell pressure, pounds gage	15.9		13.2		Feed heater not used.				Feed heater not used.		Feed heater not used.	
Feed temperature, degrees F	168		202		Aux. Exh. to stage.				Aux. Exh. to stage.		Aux. Exh. to stage.	
Average feed temperature, degrees F	188				73.3				64.5		68.4	
Fuel-oil pressure pumps, D. S. P. M.	42		52		28		28		28		20	
Auxiliary feed pumps, D. S. P. M.	...		8		20		...		20		22	
Temperature, Stack No. 1, degrees F.	760				...				...		...	
2, degrees F.	780						...		...		...	
3, degrees F.		778			...				418		?	
4, degrees F.			712		...				442		?	
Average stack temperature, degrees F.	760				...				430		?	


U.S.S. HENLEY
STANDARDIZATION TRIAL OFF ROCKLAND, ME.
JULY 30, 31, AND AUG. 2, 1912
R.P.M.
S.H.P.
SPEED KNOTS

DATA OF STANDARDIZATI

Number of Group	1			2			3			4			
Number of Run	1	2	3	4	5	6	7	8	9	10	11	12	
Direction	N	S	N	S	N	S	N	S	N	S	N	S	
Speed	12.101	12.526	12.013	16.575	17.084	17.170	20.845	20.479	20.959	22.484	22.708	22.388	
Average Speed for Group		12.292			16.978			20.686			22.572		
R. P. M.	221.67	228.43	218.34	300.18	312.95	313.86	380.45	377.66	381.15	424.12	422.70	421.47	4
Average R.P.M. for Group		224.22			309.99			379.23			422.75		
S.H.P.	514	534	500	1324	1537	1543	2854	2797	2856	4090	4115	4063	
Average S.H.P. for Group		521			1485			2826			4096		
Main Steam Lbs. Gage	265	268	262	260	260	260	251	256	258	270	266	266	
Auxiliary Exhaust "	4	5	4.5	9	6	6	6	7.5	8.5	7.5	7	9	
Feed Heater Shell "	—	—	—	—	—	—	—	—	—	—	—	—	
STARBOARD TURBINE													
Number of Nozzles	2	2	2	2	2	2	4	4	4	5	5	5	
Steam Chest Pressure Lbs.Abs.	175	180	177	270	267	267	252	253	263	264	264	265	
First Stage " "	18	19	18	26	25	25	42	41	42	51	52	53	
Fifth " " "				8.5	7.9	8.4	11.5	12	12.5	13.2	13.8	13.8	
Turbine Exhaust In. of Hg.	27.75	27.5	27.5	28	27.5	27.25	27.5	26.25	25.75	26.5	26.5	26.25	
Condenser Vacuum "	28	28	28	28.1	28	27.65		26.75	26.1	26.75	26.8	26.6	
Injection Temperature °Fahr.	56	56	56	56	56	56	57	58	58	58	58	58	
Discharge " "	74	74	74	74	76	76	76	76	76	80	80	80	
Air Pump Disch. " "	60	64	64	62	62	60	66	66	62	65	65	66	
PORT TURBINE													
Number of Nozzles	2	2	2	2	2	2	4	4	4	5	5	5	
Steam Chest Pressure Lbs.Abs.	193	198	195	273	268	268	259	255	265	267	265	265	
First Stage " "	20	19	19	25	30	30	42	46	47	55	55	56	
Fifth " " "				7.3	9.2	9.4	11.3	11.3	12.8	16.5	16.5	16.5	
Turbine Exhaust In. of Hg.	28	27.3	27.4	27.25	26.25	26	26.75	24.75	25.75	26.5	26.5	26.5	
Condenser Vacuum "							GAGE	READINGS		UNRELIABLE			
Injection Temperature °Fahr.	56	56	56	56	56	56	56	58	58	58	58	58	
Discharge " "	74	74	74	74	76	76	76	76	76	80	80	80	
Air Pump Disch. " "	60	62	62	62	62	61	63	63	62	64	64	65	

ARDIZATION TRIAL.

		5			6			7			8				
	12	14	15	16	17	18	19	20	21	22	26	27	28	29	30
	S	S	N	S	N	S	N	S	N	S	N	S	N	S	N
708	22.388	24.691	24.845	24.810	27.692	27.481	27.735	28.701	29.032	28.955	30.290	30.025	30.463	30.508	30.201
572			24.798			27.537			28.930				30.316		
70	421.47	474.92	473.96	477.42	541.84	538.98	541.95	574.54	584.14	581.92	628.67	626.41	640.37	64679	640.30
75			475.07			540.44			581.19				637.02		
15	4063	6006	6039	6106	8948	8900	9001	10449	10737	10640	12675	12661	13180	13405	13212
96			6048			8937			10641				13048		
6	266	259	260	260	255	252	260	256	259	257	246	252	254	254	253
	9	11	11.5	13	17	18	17.5	17	19	18	21	21	21	22	23
—	—	—	—	—	—	—	20	15	17	17	20	20	24	20	22
5	5	7	7	7	10	10	10	12	12	12	14	15	15	15	15
54	265	255	255	256	260	255	259	252	263	263	251	255	253	255	259
2	53	70	70	70	99	98	98	114	119	119	143	145	145	147	148
.8	13.8	17.8	17.9	18	25.5	24.5	24.7	28.5	28.7	28.5	34.5	33.75	36.5	36.8	37
.5	26.25	26	26	26	25.75	26	26	25.75	25.9	26	27	27	27	27	26.9
.8	26.6	26.4	26.4	26.5	26.15	26.3	26.3	26.25	26.2	26.2	27.5	27.45	27.4	27.35	27.35
8	58	58	58	58	58	58	58	56	56	56	56	56	56	54	56
0	80	80	84	84	86	86	86	86	86	86	86	86	88	88	88
5	66	68	68	69	72	74	72	77	77	77	88	88	92	90	90
5	5	7	7	7	10	10	10	12	12	12	14	14	15	15	15
65	265	265	265	265	263	260	265	259	266	265	258	264	262	265	264
5	56	79	78	79	108	107	108	128	130	130	138	142	139	152	152
.5	16.5	21.5	21.9	22.3							34.5	33.75	36.5	37	37
6.5	26.5	26	26	26	25.75	26	26	25.75	25.9	26	27.1	27	27.05	27	27.05
IRELIABLE															
58	58	58	58	58	58	58	58	58	56	56	56	56	56	54	56
80	80	84	84	84	86	86	86	86	86	86	86	86	88	88	88
4	65	67	67	67	72	72	72	77	80	80	86	85	84	87	86

NOTES.

FIREBRICK MELTING POINTS.

The United States Bureau of Standards has defined the melting point of firebrick as being the lowest temperature at which a small piece of brick can be seen distinctly to flow. The following melting points of important materials in firebrick were determined:

Kaolin, 1,740 degrees C.; pure Al_2O_3, 2,010 degrees; pure SiO_2, 1,750 degrees; bauxite, 1,820 degrees; bauxite clay, 1,795 degrees; chromite, 2,180 degrees. Silicon carbide begins to decompose at 2,220 degrees after prolonged heating, but does not melt at much higher temperatures with short heating. Forty-one samples of fireclay brick were tested, the melting points of which were from 1,555 to 1,725 degrees C.; eight samples of bauxite brick had melting points from 1,565 to 1,785 degrees; three of silica brick from 1,700 to 1,705 degrees; one chrome brick gave 2,050 degrees and one magnesia brick gave 2,165 degrees.—"Power."

THE WATER-GLASS METHOD OF TESTING LEAKAGE.

In an appendix to its report submitted at the last meeting, the Committee on Tests of the American Society of Mechanical Engineers suggests the following test for leakage. It is so simple that anyone may make it, and it sometimes leads to surprising results.

The water necessary to restore the water level to its height when the test was started, or which is pumped in during the test to maintain the level constant, is the amount of water evaporated, if for a given height of water in the glass there is the same amount of water in the boiler before and after the test. This may not be the case if the rate of evaporation is different, and, for the same amount of water contained, the water level is raised or lowered by the presence in the water of more or less steam bubbles. Again it may not be the case if there is a change in the relative density of the contents of the boiler and the water column. If the water column is allowed to stand without blowing until the water becomes cold, its contents will be denser and it will take a shorter column to balance the hot water in the boiler than if it were at a higher temperature. For the same height of water in the boiler the water in the gage glass will stand higher than after the contents of the column become cool. This is the reason for the recommendation that the water column should not be blown down during a water-gage test nor for a period of at least one hour before it begins.

Of the water evaporated some may be:

Lost through leakage.

Condensed in the steam pipe.

Drawn off for use.

If it is desired to determine one of these quantities, the others must be eliminated or known. If it is wished to know how much is lost by leakage, for example, it is best to eliminate the third item by not drawing any of the steam out of the system under test. The difference be-

tween the amount evaporated, as determined by the difference in the water level and the amount condensed in the pipe, is the leakage. The condensation must be drawn off and weighed. Of course it must be allowed to cool to below 212 degrees before it is exposed to the atmosphere. The appendix referred to is as follows:

"To determine the leakage of steam and water from a boiler and steam pipes, etc., the water-glass method may be satisfactorily employed. This consists of shutting off all the feed valves (which must be known to be tight) and the main feed valve, thereby stopping absolutely the entrance or exit of water at the feed pipes to the boiler; then maintaining the steam pressure (by means of a very slow fire) at a fixed point, which is approximately that of the working pressure, and observing the rate at which the water falls in the gage glasses. It is well, in this test, as in other work of this character, to make observations every ten minutes, and to continue them for such length of time that the differences between successive readings attain a constant rate. In many cases the conditions will have become constant at the expiration of fifteen minutes from the time of shutting the valves, and thereafter the fall of water due to leakage of steam and water become approximately constant. It is usually sufficient, after this time, to continue the test for two hours, thereby obtaining a number of half-hourly periods. When this test is finished, the quantity of leakage is ascertained by calculating the volume of water which has disappeared, using the area of the water level and the depth shown on the glass, making due allowance for the weight of 1 cubic foot of water at the observed pressure. The water columns should not be blown down during the time a water-glass test is going on, nor for a period of at least one hour before it begins.

"If there is opportunity for condensation to occur and collect in the steam pipe during the leakage test, the quantity should be determined as closely as desirable, and properly allowed for."—"Power."

HEAT BALANCE IN STEAM BOILERS.

By Lionel S. Marks.

SYNOPSIS.—Obtaining the heat balance of a furnace and boiler is a process of accounting for all the heat that would have been generated by the fuel if combustion had been perfect. This article develops a comparatively simple method of calculating it from the results of a complete test.

With a perfect furnace and boiler all the heat of perfect combustion of the fuel would be utilized in raising the temperature of the feed water and in evaporating it. In the best actual plants, the efficiency is from 75 to 80 per cent.; that is, from 75 to 80 per cent. of the heat of perfect combustion actually goes to the feed water. With the average plant, about 60 per cent. of the heat is utilized, while in poor plants the efficiency is still lower. When the efficiency of the plant is very low it is generally possible to ascertain the cause of its poor performance by inspection. With plants of higher efficiency it is not so easy and it becomes necessary to have recourse to flue-gas analyses and other observations. If it is desired to find out exactly what has become of the heat which should have been generated by the fuel and have gone into the feed water, that is, if it is desired to obtain the "heat balance" of the furnace and boiler, a complete test is necessary. The object of this article is to present a comparatively simple method of calculating the heat balance of a boiler from the results of such a test.

A boiler test which aims at a reasonable degree of completeness will generally include the following among the observations:

The weight of water evaporated; the temperature of the feed water, and the pressure and quality (or superheat) of the steam.

The temperature, pressure and humidity of the air, and the temperature and composition of the flue gases. The weight of coal burned; its proximate analysis and heat of combustion.

The weight and composition (or heat of combustion) of the refuse in the ash pit.

From these observations, it is possible to determine in detail what has become of the heat of combustion of the fuel. It has generally been considered necessary to add to the above observations the ultimate analysis of the coal, an analysis which must be carried out by a chemist and which is tedious and expensive. As will be shown later, it is generally possible to obtain the heat balance with an accuracy which is within the attainable degree of accuracy of a boiler test itself, without having recourse to the ultimate analysis.

The complete heat balance of a furnace and boiler takes into account five principal dispositions of the heat of perfect combustion of the fuel. They are as follows:

1. The heat utilized in raising the temperature of the feed water and in evaporating it.

2. The heat not developed as a result of incomplete combustion. This heat divides itself into three parts:

(a) The heat of combustion of the carbon and other combustible matter which has fallen into the ash pit and which is carried away with the ashes.

(b) The heat of combustion of any CO which may be going up the chimney.

(c) The heat of combustion of any hydrocarbons which may be escaping unburned with the chimney gases.

3. The heat being lost up the chimney as sensible heat of the dry chimney gases.

4. The heat being lost up the chimney in water vapor which accompanies the dry chimney gases. This water vapor comes from three separate sources:

(a) That which results from the combustion of hydrogen in the coal.

(b) That which comes to the furnace as moisture in the coal.

(c) That which arrives in the furnace as humidity in the air.

5. The heat lost by radiation and conduction, or heat which is otherwise unaccounted for.

The problem of determining the heat balance of a boiler resolves itself into the problem of finding the values of the quantities 1, 2, 3 and 4. The radiation and conduction must be determined by heat balance; it is the quantity remaining unaccounted for after all the other quantities have been determined.

The methods of determining these separate quantities are given below:

1. *Heat given to the feed water.*—This quantity is readily determined from a knowledge of the weight of water evaporated per pound of coal, the temperature of the feed water, and the pressure and quality (or superheat) of the steam. When expressed as a percentage of the total heat of perfect combustion of the fuel burned, it measures the efficiency of the boiler plant. Its value in ordinary practice varies from 60 to about 75 per cent.

2. *Heat lost by incomplete combustion.*—The object of a furnace is to burn the coal as completely as possible with the smallest possible air supply. A perfect furnace would lose no combustible matter through the grate bars into the ash pit; would convert all the carbon into carbon dioxide; would give off no unburned hydrocarbons; and would have no air of dilution; that is, would send no unused oxygen up the chimney. This perfect furnace has not yet been realized, nor is it likely to be closely approximated to with solid fuels. With liquid fuels, however, the losses

from incomplete combustion and from the admission of excess air can be reduced to a very small quantity.

(a) *The heat lost with combustible falling into the ash pit.*—To determine how much heat of combustion is lost with the refuse in the ash pit, it is necessary to know the weight of the refuse and its composition, or its heat of combustion. There are, in general, three ways of determining these quantities:

(1) An inspection of the heap of refuse at the conclusion of the test may indicate to a trained observer the approximate composition of the refuse. This method is not satisfactory by itself. The refuse is generally wet when its weight is determined, and the estimate of combustible must be preceded by an estimate of the amount of moisture. In those cases where all the combustible matter which has fallen into the ash pit is well coked, it may not be very difficult to estimate the percentage by weight of combustible in the dry refuse, and, since the combustible in that case will be carbon, it is possible to obtain the heat that would be developed by the combustion of the refuse.

A number of modern furnaces separate the green coal which sifts through the grates from the coked fuel which falls through with the ash, and in such furnaces an estimate of the combustible in the refuse may be possible. In those cases where the siftings of green coal and of coked fuels fall into the same place and are mingled together, such an estimate becomes too uncertain.

(2) The amount of combustible in the refuse can also be obtained from the total weight of coal that has been burned and the percentage of ash which the proximate analysis of the coal shows it to contain. From these quantities it is easy to calculate the total true ash, and if this is subtracted from the dry refuse in the ash pit we get the total combustible matter, but we do not get any light at all on the composition of this combustible matter. The use of the second method to check the first method has been found by the writer to work satisfactorily in those cases in which the refuse contains only coked fuel. In other cases resort must be had to the next method.

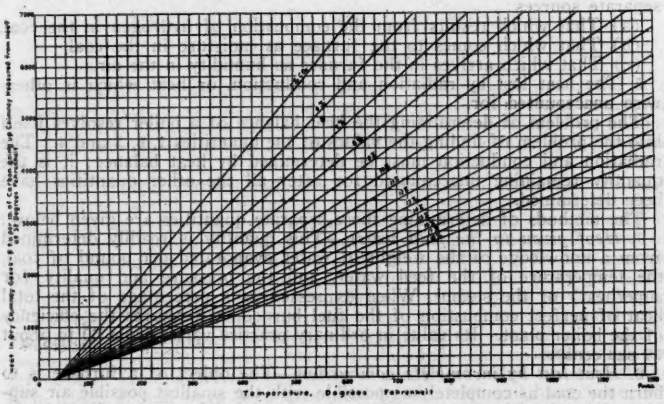


FIG. 1.—CHART FOR DETERMINING THE AMOUNT OF HEAT ESCAPING WITH THE CHIMNEY GASES.

(3) The heat of combustion of the refuse may be determined by the actual combustion of a fair sample of the refuse. This method does not give entirely satisfactory results in consequence of the great difficulty of

getting a fair sample. The refuse generally contains large clinkers, and it is often impracticable to break up all the clinkers in order to get a fairly homogeneous pile from which to begin to select a sample. The accuracy of this method depends entirely upon the accuracy with which the sample burned represents the average heat of combustion of the refuse pile.

The heat of combustion of the fuel in the refuse is seldom more than 3 to 5 per cent. of the heat of combustion of the fuel fired in well operated plants. In view of the fact that it is not possible in a boiler test to obtain an accuracy greater than 1 per cent., and generally not greater than 2 per cent., it is not important that the heat of combustion of the fuel in the refuse should be determined with very great accuracy. If an error of 10 per cent. is made in the estimate, either of the amount of combustible in the refuse or in its heat of combustion, it will make an error which generally would not be more than 3/10 of 1 per cent. in the heat balance of the boiler. In determining the heat balance of a boiler, the maximum error is likely to occur in this item.

2. (b). The heat lost by the combustion of some of the carbon to CO instead of to CO_2, is readily determinable from the flue-gas analysis. Each pound of carbon burned to CO_2 gives up 14,500 B.t.u. Each pound of carbon burned to CO gives up only 4,450 B.t.u. Consequently, for each pound of carbon burned to CO there is a loss of 10,050 B.t.u. If there is any CO present its amount will be determined by the flue-gas analysis. The weight of carbon in a cubic foot of CO_2 is the same as the weight of carbon in a cubic foot of CO at the same pressure and temperature. Consequently, the weight of carbon burned to CO has the same ratio to the weight burned to CO_2 as the volumes of the two gases. If $x =$ the percentage of the total carbon burned to CO_2, and y the percentage burned to CO, then $x + y$ is the total carbon burned and

$$\frac{y}{x+y}$$

is the fraction burned to carbon monoxide. Consequently,

$$10{,}050 \times \frac{y}{x+y}$$

is the heat of combustion lost through the burning of carbon to carbon monoxide per pound of carbon going up the chimney. This can be expressed in B.t.u. per pound of coal fired when the analysis of the coal, and the percentage of the total carbon falling through into the ash pit are known.

With good operation of the furnace there should not be more than a trace of CO except in those cases where the furnace is being forced very much beyond its proper capacity. If the CO present exceeds 1 or 2 per cent., it may safely be inferred that the incomplete combustion which this indicates extends also to the hydrocarbons.

2. (c) Heat lost with hydrocarbons escaping unburned up the chimney.

Whenever visible smoke escapes from a chimney it is probable that some hydrocarbons are escaping unburned. The denser the smoke, other things being equal, the greater is the probability of the loss of unburned hydrocarbons. The ordinary flue-gas analysis does not give any definite indication of the presence of these gases. Under normal conditions of operation of steam plants, with not more than a trace of CO and with little or no visible smoke, one may feel pretty sure than there is no appreciable loss of hydrocarbons up the chimney. In other cases there may be such a loss, but there is no available means of determining its amount. Special tests and also the heat balances of many boilers indicate that this loss is normally quite negligible.

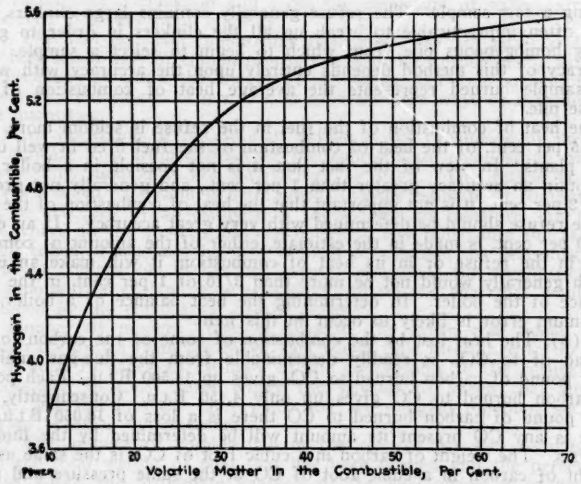


FIG. 2.—CHART FOR DETERMINING HYDROGEN FROM THE PERCENTAGE OF VOLATILE MATTER.

3. *Heat lost with the dry chimney gases.*—The gases escaping up the chimney are carbon-dioxide, oxygen, carbon-monoxide and nitrogen. These are usually collected over water and measured over water. They are, consequently, saturated with water vapor and their analysis shows nothing at all about the content of water vapor of the gases as they are going up the chimney. The heat carried away by these gases is the heat that would be given up by cooling the dry gases from the chimney temperature to the temperature of the air in the boiler room. The amount of this heat for each of the constituents is equal to

$$wC_p\ (T_c - T_a),$$

where

w = Weight of each of these constituents per pound of carbon going up the chimney;
C_p = Mean specific heat at constant pressure from the boiler-room temperature up to the temperature of the chimney;
T_c = Temperature of the chimney;
T_a = Temperature of the entering air.

The specific heat of the gases going up the chimney varies with the temperature, and, according to the best authorities, the mean specific heat from 32 degrees to any temperature t degrees, is as follows:
For

Oxygen	$C_p = 0.2125 + 0.00001\ (t - 32)$
Nitrogen	$= 0.243 + 0.000012\ (t - 32)$
Carbon monoxide.....	$= 0.243 + 0.000012\ (t - 32)$
Carbon dioxide.....	$= 0.201 + 0.00041\ (t - 32)$ $- 0.000000055\ (t - 32)^2$

To facilitate the calculation of the total heat escaping up the chimney, the chart, Fig. 1, has been prepared. In this chart the horizontal scale gives the temperature of the gas; the vertical scale gives the sensible heat being carried away by the gases in B.t.u. per pound of carbon going up the chimney. The lines are labeled according to the percentage of CO_2 which analysis shows to be present. These curves are calculated on the assumption that the gas contains (in addition to the percentage of carbon dioxide marked on the curves) 80 per cent. of nitrogen, and that the rest of the gas is oxygen. In those cases where some CO is present the correction is quite negligible if the CO is reckoned as CO_2. For example, with 15 per cent. of CO_2 and 2 per cent. of CO, and with a chimney temperature of 632 degrees F., the heat of the gases is 2,183 B.t.u. If it is assumed, for the purposes of this calculation, that the CO acts as CO_2, we have 17 per cent. of CO_2, the sensible heat of which is 2,200 B.t.u.; the difference is only 17 B.t.u. In using Fig. 1 the heat contained in the gases at boiler-room temperature must be subtracted from the heat at chimney temperature in order to find the heat carried away by the dry gases.

The amount of heat escaping with the dry gases up the chimney can readily be expressed, as a percentage of the total heat of perfect combustion when the relation of the carbon escaping up the chimney to the weight of fuel has been determined from the proximate analysis of the fuel, and the correction has been made for the carbon falling through into the ash pit.

4. The heat escaping up the chimney with the water vapor is equal to the total heat of this vapor minus the heat which it has when at the temperature of the room. It is necessary, however, to decide whether the vapor must be considered in the vapor or the liquid form at this lower temperature. This question is decided separately under each of the following headings:

(a) The moisture resulting from the combustion of hydrogen in the coal.

To determine the amount of this water vapor it is necessary to know how much hydrogen is present in the dry coal. The usual way of determining this quantity has been to make the so-called ultimate analysis of the coal, which determines not only the hydrogen but also the total carbon, oxygen, nitrogen and sulphur. As already pointed out, this determination is tedious and expensive. It is possible to determine the hydrogen from the proximate analysis with a degree of accuracy which is sufficient for all ordinary purposes. As was pointed out by the writer in an article in "Power," Vol. 29, page 928, December, 1908, there is a definite relation between the hydrogen content of the combustible matter of American coals and the total amount of the volatile matter expressed as a percentage of the total combustible of the coal. This relationship is shown on the accompanying curve, Fig. 2.

Professor Diederichs has deduced an equation for this curve of the form

$$H = v\left(\frac{7.35}{v+10} - 0.013\right)$$

where

H = Percentage weight of hydrogen in the combustible;

v = Percentage weight of volatile matter in the combustible.

By the use of either the curve or the equation it is possible to determine the hydrogen content of a coal with an accuracy of about 2/10 of 1 per cent.

The carbon in the volatile matter of the coal is determinable with less accuracy by the curve shown in Fig. 3. The error in this case may be as much as 2 per cent. for the more common fuels, while for lignites and

other special fuels it may be even greater. The total carbon in coal is the sum of the fixed carbon and of the carbon in the volatile matter. If this latter is determined by the use of Fig. 3 the total carbon per pound of coal can be readily determined.

Assuming that it is sufficiently accurate to take the hydrogen and carbon content of the volatile combustible matter of a coal from the two curves given, it becomes possible to get the practical equivalent of that part of the ultimate analysis of the coal which is required for the calculation of a heat balance.

When hydrogen burns to H_2O, its weight increases ninefold; consequently, the weight of water vapor resulting from the combustion of hydrogen is immediately determinable. The heat carried up the chimney by this moisture is given by the equation

$$Q = w(H - h)$$

where

w = Weight of the H_2O formed per pound of coal burned;
H = Total heat per pound of steam at chimney temperature;
h = Heat of one pound of water at boiler-room temperature.

The total heat H of water vapor at ordinary chimney temperatures and at the pressures commonly occurring in the chimney is practically independent of the pressure, and is given in Fig. 4. The heat of one pound of water h at the temperature of the boiler room may be taken as the boiler-room temperature minus 32.

(b) Moisture in the coal.

The proximate analysis of the coal gives the total weight of moisture content in the coal. The heat which it carries up the chimney is calculated as in the previous paragraph.

(c) Moisture entering with the air.

Air, under ordinary atmospheric conditions, contains some water vapor. The weight of this vapor cannot exceed the weight of an equal volume of dry and saturated steam at the same temperature. The accompanying curves, Fig. 5, show approximately the ratio of the heat carried up the chimney by the dry chimney gases to the heat being carried away by the water vapor which entered with the air. As this latter quantity is always a small fraction of the heat of the dry chimney gases, it is not necessary to calculate its amount exactly. The curves have been calculated on the assumptions that the specific heat of water vapor is twice that of the chimney gases, and that the chimney gases have the physical properties of air. By reference to the curves it will be seen that with air at 80 degrees F. and humidity 80 per cent., the heat being carried up the chimney with the moisture which entered with the air, is 1/34 or 3 per cent. of the heat of the dry chimney gases. The chimney gases seldom carry off more than 15 per cent. of the heat of perfect combustion of the coal. Assuming this amount, the total heat in the water vapor under the suggested conditions is

$$1/34 \times 15 = 0.5 \text{ } \textit{per cent.}$$

approximately of the heat of perfect combustion of the coal. This quantity is seldom exceeded. The loss is commonly not more than 0.2 to 0.3 per cent.

5. Any heat not accounted for under the preceding headings is assumed to be lost by radiation and conduction. This unaccounted for quantity is seldom less than 2 per cent. of the heat of perfect combustion and may be as much as 4 or 5 per cent. Any test in which this quantity falls outside the limits of 2 and 5 per cent. should be looked upon with suspicion until some explanation has been found. The writer has come across a number of tests showing high efficiencies in which this unac-

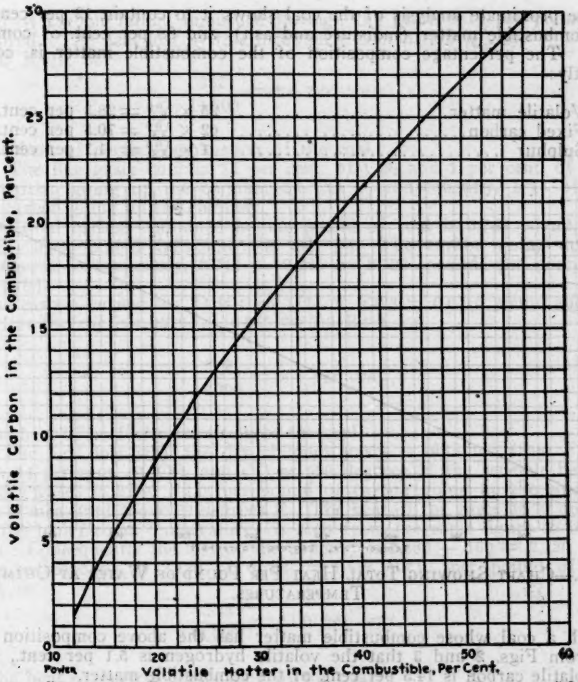


FIG. 3.—CHART FOR DETERMINING THE CARBON IN THE VOLATILE MATTER.

counted for quantity has a negative value. Such tests must be rejected as worthless.

As an example of the determination of the heat balance of a boiler plant, we may assume the following data from a boiler test:

Weight of feed water evaporated per pound of coal fired, pounds	9
Temperature of the feed water, degrees F	90
Pressure of the steam, absolute, pounds per square inch	160
Superheat of the steam, degrees F	60
Temperature of the air entering the boiler room, degrees F	70
Humidity of the air entering the boiler room, per cent	60
Temperature of the flue gases, degrees F	550
CO_2 in the flue gases by volume, per cent	13
CO in the flue gases by volume, per cent	1
Heat of combustion of the coal as fired, B.t.u.	14,000
Proximate analysis of the coal:	
Moisture, per cent	4
Volatile matter, per cent	25
Fixed carbon, per cent	62
Ash, per cent	9
Sulphur, per cent	1
Weight of refuse in the ash pit per pound of coal fired, pound	0.131
Estimated moisture in the refuse by weight, per cent	20
Estimated carbon in the dry refuse by weight, per cent	30

The proximate analysis of the coal shows it to contain 12 per cent. of noncombustible matter (moisture and ash), and 88 per cent. of combustible. The percentage composition of the combustible matter is, consequently:

Volatile matter	$25 \times \frac{100}{88} = 28.3$ per cent.
Fixed carbon	$62 \times \frac{100}{88} = 70.5$ per cent.
Sulphur	$1 \times \frac{100}{88} = 1.1$ per cent.

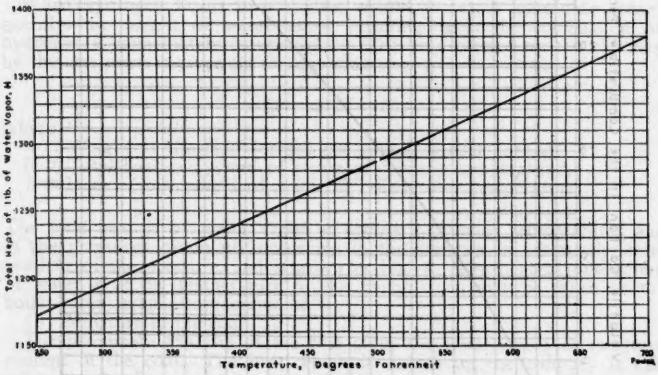


FIG. 4.—CHART SHOWING TOTAL HEAT PER POUND OF WATER AT CHIMNEY TEMPERATURES.

With a coal whose combustible matter has the above composition we see from Figs. 2 and 3 that the volatile hydrogen is 5.1 per cent., and the volatile carbon is 14.5 per cent. of the combustible matter.

The total carbon is $14.5 + 70.5 = 85$ per cent. of the combustible, or

$$85 \times \frac{88}{100} = 74.8 \textit{ per cent.}$$

of the coal as fired.

From the above data we determine the heat balance as follows:

1. The heat given to one pound of water is found from the steam tables to be

$$1230 - 58 = 1172 \text{ B.t.u.}$$

Consequently the heat absorbed by the feed water per pound of coal fired is

$$9 \times 1172 = 10{,}548 \text{ B.t.u.}$$

The efficiency of the boiler is

$$\frac{10{,}548}{14{,}000} = 75.3 \textit{ per cent.}$$

2a. The refuse in the ash pit is 0.131 pound per pound of coal fired. An estimate of 20 per cent. of moisture gives 0.105 pound of dry refuse, and the further estimate of 30 per cent. of carbon in the dry refuse gives 0.031 pound of carbon, and 0.074 pound of ash per pound of coal fired.

The proximate analysis of the coal shows that the ash should be 0.08 pound. This is a fairly good check. Assuming that the amount of ash given by the proximate analysis is correct, we find $0.105 - 0.08 = 0.025$

pound of carbon falling unburned through the grate bars per pound of coal fired. The heat lost by this incomplete combustion is $0.025 \times 14{,}500 = 362$ B.t.u., or

$$\frac{362}{14{,}000} = 2.6 \textit{ per cent.}$$

of the heat of perfect combustion of the coal.

2b. The flue gases contain 13 per cent. of CO_2 and 1 per cent. of CO. The carbon going up the chimney as CO is, consequently, 1/14 of the total carbon going up the chimney.

The total carbon contained in one pound of coal is 0.748 pound, and of this 0.025 pound falls into the ash pit. The carbon going up the chimney is, consequently, $0.748 - 0.025 = 0.723$ pound per pound of coal fired.

The carbon burned to CO is then $1/14 \times 0.723 = 0.0516$ pound and the heat lost thereby is $0.0516 \times 10{,}050 = 519$ B.t.u., or,

$$\frac{519}{14{,}000} = 3.7 \textit{ per cent.}$$

of the heat of perfect combustion of the coal.

3. The heat lost with the dry chimney gases is obtained from Fig. 1. With 14 per cent. of CO_2 and CO at 550 degrees F. the sensible heat of the dry gases is 2,280 B.t.u. per pound of carbon going up the chimney. This is measured above 32 degrees F. The heat of the gases at 70 degrees F. (the boiler-room temperature) is seen from the same figure to be 160 B.t.u. Consequently the loss up the chimney is $2{,}280 - 160 = 2{,}120$ B.t.u. This corresponds to $2{,}120 \times 0.723 = 1{,}533$ B.t.u., per pound of coal fired, or

$$\frac{1{,}533}{14{,}000} = 11.0 \textit{ per cent.}$$

of the heat of perfect combustion of the coal.

4a. The moisture resulting from the combustion of the hydrogen in the coal is 9×0.051 pound per pound of combustible, or $9 \times 0.051 \times 88/100 = 0.404$ pound per pound of coal fired. The heat which it carries with it is seen by reference to Fig. 4, to be $0.404\ (1{,}310 - 58) = 505.8$ B.t.u., or

$$\frac{505.8}{14{,}000} = 3.6 \textit{ per cent.}$$

of the heat of perfect combustion of the coal.

4b. The moisture in the coal is 0.04 pound per pound of coal. The heat which it takes up the chimney is $0.04\ (1{,}310 - 58) = 50.1$ B.t.u., or, 0.4 per cent., approximately, of the heat of perfect combustion of the coal.

4c. With air at 70 degrees F., and humidity 60 per cent., the vapor entering with the air is seen from Fig. 5 to carry up the chimney 1/62 of the heat of the dry chimney gases. This heat has been seen to be 11 per cent. of the heat of perfect combustion of the coal. The loss due to the moisture in the air is consequently

$$\frac{11.0}{62} = 0.2 \textit{ per cent.}$$

approximately.

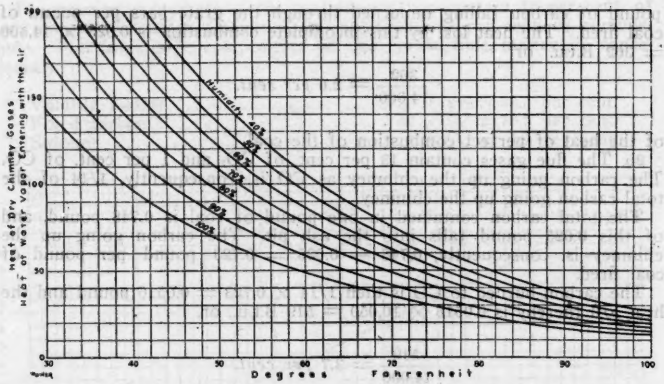


FIG. 5.—CHART SHOWING AMOUNT OF HEAT CARRIED UP THE CHIMNEY BY THE WATER VAPOR OF THE AIR.

5. The heat lost by radiation and conduction, or otherwise unaccounted for, is obtained by balance. The disposition of the heat is seen to be as follows:

	Per cent.
Heat given to the feed water	75.3
Loss by unburned carbon in ash pit	2.6
Loss by CO up the chimney	3.7
Loss with dry chimney gases	11.0
Loss with moisture from hydrogen in the coal	3.6
Loss with moisture in the coal	0.4
Loss with moisture in the air	0.2
Radiation, conduction, etc	3.2
	100.0

As was pointed out earlier, the use of the curve in Fig. 3 for determining the carbon in the volatile matter of a coal, may give results which are in error by 2 per cent. or more. To ascertain the influence of such an error on the heat balance the preceding calculations have been repeated, taking the volatile carbon as 16.5 per cent. instead of 14.5 per cent. shown by the curve. The only changes which this produces is to increase item 2 (b) by 0.1 per cent., item 3 by 0.3 per cent., and consequently to reduce item 5 by 0.4 per cent. These changes are unimportant and justify the use of Fig. 3.—"Power."

ONE CAUSE OF CORROSION.

A cousin to that famous (or infamous) worm that for years has been eating the life out of steel rails has been found, or is in process of being found, in the form of an insect that destroys cast-iron pipe! Breaks in water mains at Syracuse, N. Y., according to the "Journal" of that city, showed the cast iron softened so that it could be cut like lead. A water-pipe manufacturer, whether the one who made the pipe does not appear, is said to have written to a Syracuse official advancing the theory that "some minute insects, which frequented the water there (at Atlantic City,

N. J.) exuded an acid secretion, which in conjunction with the salts in the water, set up an electrolytic action and softened the pipe. Perhaps this is the case at Syracuse."

It is further stated that some of the Syracuse pipe has been turned over to the Chemical Department of Syracuse University for investigation. Ought it not to have gone to the Department of Biology, Division of Entomology? Or, perchance to the Division of Parasitology, since, whatever the form of life, this cast-iron pipe eater is unquestionably a parasite.—"Engineering News."

TOOL STEEL FOR THE U. S. NAVY.*

By Lewis Hobart Kenney, B. S., M. E.

INTRODUCTION.

Previous to 1909 each navy yard prepared requisitions for the purchase of tool steels for its own purposes. The requisitions specified either that proprietary material be purchased or that the award of contract be based on information obtained by a test of some description on samples submitted by the bidders. But by this method there could be no uniformity in the specifications of the navy yards, so in order to centralize the purchasing and to standardize the tool steels, a tool steel board, in 1909, recommended that the Philadelphia Navy Yard be the purchasing station; and it prepared specifications for one "high speed" and for three grades of carbon tool steel. The specifications are given in Appendix A.

The chemical composition of this "high speed" tool steel differed from that of any of the commercial tool steels, but the chemical composition of each grade of carbon tool steel corresponded to that of commercial tool steels. The three grades of carbon tool steel varied principally in the carbon content, in order to adapt them to the purposes for which such tool steels are generally used. The contracts were awarded under these specifications to the lowest responsible bidders for tool steel of a chemical composition within the specification limits. The specifications required, as a part of the inspection for acceptance of the material, physical tests in addition to chemical analyses; but these physical tests never gave satisfactory or decisive results, and proved conclusively that it was advisable to revise the specified chemical compositions. The specifications did not provide a means for ascertaining the relative merits of the tool steels offered by the bidders or for learning if there were tool steels superior to those within the limits of the chemical compositions specified.

In order to overcome the above objections it was considered advisable to revise the specifications given in Appendix A. Such specifications should require the bidders to submit samples of the tool steels which they offer. The samples should be manufactured into tools and subjected to physical tests devised to investigate their relative merits. The data thus obtained should form the basis for recommending the award of contract. The chemical compositions should be given with maximum and minimum limits, in order to indicate to the bidder the kind of tool steel required, but as the physical test would form the basis for recommending the award of contract, a statement should be included to the effect that the bidders could submit samples of chemical compositions differing from those specified. One object of these provisions was to introduce competition as to the qualities of the tool steels instead of competition simply in price, and another object was to provide a means for learning something of the relative merits of the commercial tool steels, and for taking advantage

* Read at the meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 21 and 22, 1912. Reprinted by permission of that Society.

of the developments and progress made by the manufacturers in this industry. By this means definite information could be obtained concerning the qualities of the tool steels before the contracts were awarded for their purchase. The possession of such information is unquestionably of the most vital importance in preparing a recommendation for award of contract.

The study of tool steels, which the adoption of specifications as outlined above made possible, is under the direction of the Engineer Officer, Navy Yard, Philadelphia, Pa. The subject is practically divided into the two general classifications of "high speed" tool steel, or tungsten tool steel, class 1, as it has been designated in the later specifications, and carbon tool steels. The "high speed" tool steel was considered the more important and its study was, therefore, undertaken first. In order to eliminate repetition this paper has been divided into the following sections:

(*a*) Tungsten tool steel, class 1, development of specifications.
(*b*) Carbon tool steels, development of specifications.
(*c*) Description of selective tests.
(*d*) General notes.

Sections (*a*) and (*b*) have been subdivided to represent the successive schedules under which tool steels were purchased. Only "high speed" tool steel was purchased under Schedule 3244, but tungsten tool steel, class 1, and carbon tool steel, classes, 1, 2, 3, and 4, were purchased under Schedules 3893 and 4469.

TUNGSTEN TOOL STEEL, CLASS 1.

Schedule 3244.—The first revision of the tool steel specifications in accordance with the scheme outlined above was for the purchase of "high speed" tool steel for the U. S. Naval Academy, the specifications for which are given in Appendix B. The limits of the chemical composition were varied from those given in the existing specifications (Appendix A) in order to permit bidders to submit proposals on their commercial standard tool steels, and the feature of a selective test was introduced. The selective test provided means for investigating the relative suitability, for the purposes intended, of the tool steels offered by the bidders, and the recommendation for award of contract was based on the information thus obtained. In order to obtain samples of tool steel for the selective test the specifications required each bidder to furnish a sample bar of the tool steel he offered; and this sample bar was delivered to the engineer officer for him to direct the selective test. The heat treatment of the tools, their chemical analysis, the conditions of the physical test, and the computations necessary to determine the award of contract constitute the selective test. A lathe tool selected for the physical test was kept cutting, without lubricant, until it failed by the sudden breaking down of the cutting edge due to heating caused by the friction of the chip; and a record of the elapsed time of run, or cutting life of the tool, was made. By keeping the other conditions constant the elapsed time of run was the principal variable. Each tool after failure was reground, care being taken to remove the effects of the heating due to the previous cut, and again tested until the tool broke down as above described, after which it was reground and tested a third time.

It was considered that the cutting life, as shown by the elapsed time of run above described, and the cost of the material were the principal factors in determining a selection, because the number of times the tools could be reforged and reground, and the cost of keeping them in efficient condition, would be practically the same, regardless of the quality of the tool steel. Therefore the ratio of the arithmetical mean of the elapsed time of all runs of the tools of one sample to the price per pound of the material was computed. It was recommended that the contract be awarded

for the purchase of the tool steel of highest "ratio." The data of this selective test are given on sheet No. 607.

An estimate was made to determine the relative values of the several tool steels tested by computing, first, the value for each sample which would give it a "ratio" equal to the highest "ratio," and second, to determine the value of the tool steel of highest ratio to obtain a ratio equal to that of each sample. The values thus computed are given on sheet No. 607.

A test under the conditions prevailing during the above selective test was made of tool steel which had been purchased under specifications, Appendix A, from four contractors in order to learn if it were equal or superior to the commercial tool steels which had just been subjected to a selective test; and it proved conclusively that some of the commercial tool steels were superior. The data of this test are given on sheet No. 607.

Schedule 3893.—The information obtained from the selective test under Schedule 3244 indicated that it was advisable again to revise the specifications for the following reasons:—First, to more clearly explain the requirements to the bidders, and second, to utilize the information obtained in preparing more rigid specifications.

The analyses of the sample bars submitted under Schedule 3244 were utilized in preparing the chemical compositions for the specifications, and the limits of the elements were made broad enough to include the best grades of "high speed" tool steel. For purposes of classification, the "high speed" tool steel was designated as tungsten tool steel, class 1, in the specifications.

These specifications, which are given in Appendix C, required a selective test similar in character to that previously described. The purposes for which the tool steels are, in general, adapted was inserted in the specifications to assist navy yards in selecting tool steels adapted to their needs, and also as a guide for bidders in case they should desire to submit, for selective test, tool steels of a composition differing from that specified. The conditions throughout the selective test were kept as nearly uniform as facilities would permit so that the principal variable was the elapsed time of run, or cutting life of the tool. With all the care exercised, variations in the elapsed time of run occurred for each sample, and, in order to determine if any of the observations of the elapsed time of run should be rejected, they were adjusted by the principles of least squares.

During this test a volt meter and ammeter were used to determine the input to the motor which drove the test lathe, in order to obtain a measure of the work done by the nose of the tool. The ammeter readings varied for the different tools, due principally to slight variations in depth of cut and cutting speed, which indicated that the work done by the different tools was not the same, and in order to allow for this difference in computing the selective factor a quantity was introduced called "work value," which is the product of the mean elapsed time of run of all tools of one sample and the mean watts required to drive the lathe minus the friction watts. The work value, therefore, is the watt-minutes of work done by the tool.

The "work value" divided by the price per pound of the material gave the selective factor for this test. The relative values of the tool steels were computed as previously described, and the data of this test, together with the chemical analyses of the tool steels, are given on sheet No. 1058.

Schedule 4469.—Another revision of the specifications was considered necessary after the above selective test had been completed, in order that advantage might be taken of the additional information obtained, and the feature of a selective test was continued. The new specifications are given in Appendix D.

The selective test was conducted under uniform conditions as previously described, so that the principal variable was the elapsed time of run of the tools. Electrical observations were made of the input to the motor which drove the test lathe. They showed, as on the previous test, that the work done by the tools varied. It was therefore decided to compute the "work value" or watt-minutes of work done by each tool first, and then adjust the "work values" by the principals of least squares instead of elapsed time of runs, as was done in the previous test. By the previous method an observation of the elapsed time of run of a tool might vary so greatly from the mean that it would be rejected, although the watt-minutes of work done by a tool might not vary sufficiently from the mean work value to necessitate rejection. The work done by a tool, which is indicated by the elapsed time of run and the watts consumed, is an important factor in determining selection, and it was therefore decided that the "work value" of each tool was a fairer value to adjust by the principles of least squares than the elapsed time of runs. The relative values of the tool steels were computed as previously explained, and the data of this test, together with the chemical analyses of the tool steels, are given on sheet No. 1520.

A test was made of the tools which obtained the highest selective factor under Schedule 3893 under the same conditions as the above selective test, and the data are recorded under the heading "4 Schedule 3893" on sheet No. 1520.

CARBON TOOL STEELS.

Schedule 3893.—The information obtained from the selective test conducted under Schedule 3244 indicated that it was advisable to revise the specifications for carbon tool steels given in Appendix A, and a selective test similar in character and purpose to that previously described was introduced. Four classes of carbon tool steel were selected which varied principally in their carbon content. The specifications finally prepared are given in Appendix C. The conditions throughout the selective test were maintained as nearly constant for each class of tool steel as facilities would permit, and the elapsed time of run, or operating life of the tools, was the principal variable in the test, because the tools were operated until they broke down.

The milling cutters for the selective test of carbon tool steel, classes 1 and 2, are shown on sheet No. 1058. These cutters were operated until they broke down either in the shank or teeth. The elapsed time of run of the cutters was recorded and represents the total time the cutters were operating, but does not include the time required to return the milling machine table to the starting point and to set for the next cut. The selective factor represents the ratio of the mean elapsed time of run of all cutters of one sample to the price per pound of that sample.

The selective test tool for class 3 carbon tool steel was a pneumatic cape chisel, shown on sheet No. 1058. The chisels were operated until they failed either by the breaking of the cutting edge, dullness, or wearing of the sides, so that the length of the cutting edge was reduced. The chisels were reground and given a second test, and the total distance cut was recorded. The selective factor represents the ratio of the mean distance cut by the chisels of one sample to the price per pound of that sample.

A button-head rivet set was used as the selective test tool for carbon tool steel, class 4, and is shown on sheet No. 1058. The sets were tested by driving a certain number of hot rivets, and their condition after the test was observed and a record made of the comparative conditions. No selective factor was computed because the test is not so decisive as the preceding tests, but this class of tool steel is, of course, not intended for cutting tools.

The data of the selective tests, the chemical compositions, and the rela-

tive values computed for the above classes of carbon tool steel are given on sheet No. 1058.

Schedule 4469.—After the selective test of Schedule 3893, it was considered advisable to revise the specifications for reasons similar to those previously given. The new specifications are given in Appendix D.

The conditions throughout the selective test were maintained as nearly uniform as facilities would permit, and the operating life of the tools determined as previously described. Before the tools were treated a determination was made of the decalescent point of each sample to assist in selecting suitable treating temperatures. The heating and cooling curves of the samples are given on sheet No. 1521.

Some of the bidders took advantage of the clause in the specifications which permitted tool steels to be submitted of a chemical composition differing from that specified. Tool steels containing tungsten were submitted under carbon tool steels, classes 1 and 2, and a tool steel containing chromium was submitted under carbon tool steel, class 3.

The selective test tools used are shown on sheet No. 1521, and it will be noted that the milling cutter is the only one changed from the selective test tools shown on sheet No. 1058. The change in the milling cutter was made in order to support the outer end so that it could better withstand the strain of the test. The method of conducting the selective test was similar to that described for the preceding schedule. It was at first intended to adjust the observations of this test by the principles of least squares, but the variations of the observations were such that it was decided the results thus obtained would not warrant the labor involved. Observations, therefore, which were considered to be not fairly representative, were rejected.

The specifications, Appendix C, contain a tungsten tool steel, class 2, which was intended as an intermediate tool steel between the carbon tool steel, class 1, and the tungsten tool steel, class 1, but it was omitted from the specifications, Appendix D. A small quantity of tool steel under these specifications had, however, been purchased, and in order to learn how it compared with the tool steels tested under the above selective test, milling cutters were made, treated and tested under identical conditions.

The data of the selective tests, the chemical compositions and the relative values computed for the above classes of carbon tool steel are given on sheet No. 1521.

DESCRIPTION OF SELECTIVE TESTS.

Tungsten Tool Steel, Class 1.—The five tools made from the sample bars are stamped with the schedule number, with an index number which is assigned to each sample, and with consecutive numbers for the tools of one sample. All tools are hand-forged to the No. 30 lathe tool form of the Sellers system of tool forms. The following day the tools are treated, two furnaces being required for this purpose. In one furnace a temperature of 1,600 degrees to 1,700 degrees F., and in the other a temperature of 2,400 degrees to 2,450 degrees F., are maintained. The cutting ends of the tools are uniformly heated in the low-heat furnace and then in the high-heat furnace. The temperatures given above do not indicate the temperature of the cutting end of the tool because the temperature is lower there than where the thermo-couple is. Uniform heat treatment is difficult to attain owing to the existence of a temperature gradient in the tool itself and the heat loss through the opening of the furnace for the insertion of the tool, resulting in a sharp temperature gradient at the opening of the furnace. In order to reduce the heat losses and the temperature gradient to a minimum and to obtain a satisfactory temperature for treating the cutting end of the tool, it is necessary to close with bricks the opening into the furnace so that it is just large enough to admit the tool. After the tools are removed from the high-heat furnace they are cooled by dipping the cutting end into oil, or they may be cooled by

directing on it a heavy blast of compressed air. The oil is agitated by compressed air and is cooled to maintain a constant temperature. Oil was used for these tests and is considered preferable because it is less noisy and less expensive than compressed air, and tests which have been made indicate that better results are obtained by oil cooling. The tools are cooled in the oil until they are black hot, when they are removed and placed on a cooling table.

After the heat treatment the tools are ground to the No. 30 Sellers system of lathe tool forms and later tested on a nickel-steel forging. All tools of a selective test are tested on one forging because it has been impossible to obtain nickel-steel forgings of identical characteristics chemically and physically. The depth of cut, feed and cutting speed are constant throughout a selective test so that the principal variable is the elapsed time of run, or the cutting life of the tools. All tools are tested to destruction, after which they are reground and retested until each tool has been tested three times.

The action of the tools when cutting is very interesting, indicating that the material is torn from the forging instead of being cut. The chip wears at first a depression in the face of the tool back of the cutting edge, and the heat generated by the friction of the chip softens the tool. The generation of heat and wearing away of the tool continue until the depression, increasing in size, finally reaches the cutting edge, which suddenly breaks down and concludes the test for that tool. The action of the chip is shown on Plate 1. It is necessary to grind off about 3/32 of an inch from the top and end of the tools to remove the effects of heating.

A volt meter and ammeter were used and later a graphic watt-meter to determine the input to the motor of the test lathe. By this means the average watts of the friction and cutting loads, which were found to be nearly constant, were determined; the difference being the net watts which, multiplied by the elapsed time of run of the tool in minutes, gave the work done by the nose of the tool measured by the resistance the forging offers to it.

The elapsed time of run for a tool depends somewhat upon the dissipation of heat generated by the friction of the chip. The dissipation is accomplished by conduction in the tool and forging and by radiation, since no lubricant is used. It has been noted generally that the steel forgings on which the tools are cutting will heat up considerably if they are of small diameter and operated at a high number of revolutions per minute. The elapsed time of run decreases as the temperature of the forging which the tool is cutting increases, and tests made when the room temperatures are far apart are not readily comparable Also, due to the differences in the test forgings used, the selective tests conducted from time to time are not readily comparable.

Carbon Tool Steels.—Each sample submitted for selective test under Schedule 4469 was tested to determine the decalescent point. The heating and cooling curves are given on sheet No. 1521. All tools were heated to a temperature slightly above the decalescent point and quenched in brine, after which the temper was drawn in a lead bath. The cutting tools were then ground and were ready for the selective test.

The proportions of the milling cutter used for the selective tests for carbon tool steel, classes 1 and 2, shown on sheets Nos. 1058 and 1521, were adapted from an article by Mr. A. L. Deleeuw, in the Transactions of the American Society of Mechanical Engineers. The principal difference from milling cutters in general use is in the comparatively small number of teeth permitting a larger clearance for the chips. This cutter is so small that it was necessary to support the outer end to enable it to stand the heavy cut desired to give a break-down test similar in purpose to that developed for tungsten tool steel, class 1. The cutter was operated at the speed of 370 revolutions per minute, feed 20 inches per minute, and 0.08 of an inch depth of cut through the full table travel of the

milling machine. The table was run back to the starting point and reset as often as necessary until the cutter failed. The cutter was run without lubricant in order to make the test as severe as possible and there was a generation of heat similar to that developed by the tungsten tool steel, class 1, test, and blue chips were occasionally produced. The cutters made of carbon tool steel would become so hot that they would twist off in the cutting part of the tool, but the cutters made of tool steel containing tungsten, although operating at equal temperatures, would twist off in the shank. The former phenomenon is due to the drawing of the temper of the carbon tool steels, but the introduction of tungsten apparently prevents this action, enabling the tools to withstand heat break-down. The cutting edge of the tools containing tungsten would dull gradually, thereby increasing the tortional stress which ultimately equalled the physical strength of the material. The effect of tungsten is also shown in the greatly lengthened elapsed time of run or cutting life of the tools. The cutters are shown on Plate 2.

The heat treatment for these tool steels containing tungsten is not different from that of carbon tool steels; so that their introduction to the navy yards will cause no change in the present methods of treating tool steels, and there will be the added advantage of a much superior cutting tool steel.

The cape chisel used for the class 3 carbon tool steel selective test is shown on sheets Nos. 1058 and 1521. In some of the early tests and in the yard generally trouble was experienced by the occasional breaking of the shank of the hammer end of the chisel. But this trouble has been overcome so far as the selective tests are concerned, and reduced so far as the yard is concerned, by treating about half an inch of the hammer end of the body with the shank and quenching by dipping about three-fourths of an inch of the shank into brine for a few seconds, and then the entire tool. The cutting end is treated at the same temperature as the hammer end and the temper of both ends drawn by submerging the chisel in a molten lead bath at the desired temperature. One of the samples submitted under this class contained chromium, and the heating and cooling curve showed that a higher temperature was needed for treating, and the test showed that the temper should be drawn at a higher temperature than for the carbon tool steels.

It has been noted when making tests of the chisels that the heat treatment does not extend back far from the cutting edge, and there is only a short distance on the tool where the maximum cutting life can be obtained. If the chisel proved to be brittle on the first test, indicating that the temper had not been drawn sufficiently, in all probability the second test would be more satisfactory, while a third test might show that the chisel was too soft.

The button-rivet set used for the class 4 carbon tool steel is shown on sheets Nos. 1058 and 1521. The set was heated to the desired temperature and quenched in brine, after which the temper was drawn in a lead bath. Each set drove a certain number of hot rivets, and an observation of its condition was made after the test, but this is not a test to destruction as are the preceding tests, and is, therefore, not so decisive.

GENERAL NOTES.

Earlier in this paper the statement was made that the observations of the elapsed time of run for the selective test of tungsten tool steel, class 1, data for which are shown on sheet No. 1058, were adjusted by the principles of least squares. By referring to that sheet it will be noted that four observations were rejected, and by referring to sheet No. 1520 it will be noted that only one observation was rejected. The terms "residual" and "probable error" used on sheet No. 1058 were changed to "deviation" and "probable deviation" on sheet No. 1520. The observa-

tions of the carbon tool steels do not agree as closely as those for tungsten tool steel, class 1, and the causes for the variations are not very easily determined. In the case of the milling cutters the cutting life is considerably reduced if there is very much vibration, and in order to overcome this as much as possible a heavy, rigidly constructed milling machine was used. If the cutters were not exactly central in the arbor so that they did not rotate around their geometric axis, vibrations would be set up which would increase in violence until the cutter finally broke, and it was therefore necessary to fit very carefully the cutters into the arbor.

The pneumatic chisels were operated by a man, which, of course, introduced a greater variation than if a machine were used. The question as to whether or not the test should be stopped, due to the condition of the tool, is sometimes a matter of individual opinion, such as the degree of dullness, or the amount of reduction in width of cutting edge due to wearing down.

The treating temperature for the tungsten tool steel, class 1, can be varied through a short range in the vicinity of 2,250 degrees F., without producing much variation in the results of the physical test. The treating temperature of the carbon tool steels seems to be within narrower limits, which may perhaps account for some of the variations in the test. It is, of course, extremely difficult to hold the furnaces, which are of the oil-burning type, to absolutely definite temperatures.

The test of the carbon tool steel, classes 1 and 2, which contained tungsten, showed less variation than the carbon tool steels, as may be seen by referring to sheet No. 1521. This may indicate that the addition of tungsten increases the treating temperature limits slightly without effecting the results of the physical test very much. The addition of tungsten seems to produce two desirable results: increasing of the cutting life of the tools and increasing the treating temperature limits of the tool steels. Furthermore, the tool steel containing this element apparently does not require any different method of treating from that in general use for carbon tool steels.

A test was made of tools from Schedule 3244 to determine the relation between the cutting speed and the elapsed time of run, or cutting life of the tool, all conditions being maintained constant except cutting speed. The curve obtained from this test is shown on sketch No. 288.

Photomicrographs have been made of all the tungsten tool steel, class 1, tools used in the selective test for Schedule 4469 by the Naval Experiment Station, Annapolis, Md. Two photomicrographs were taken of the top face of each tool, one near the end where the chip rubbed, which has been marked "A," and the other a short distance back which has been marked "B." The following photomicrographs, shown on Plate 3, were made of tools after the selective test had been completed and the surface from which they were taken is about $\frac{1}{16}$-inch below the surface exposed to the furnace heat:

Card No. 4, B 2, from tool No. 1–2.
Card No. 8, B 4, from tool No. 2–4.
Card No. 4, B 2, from tool No. 3–2.
Card No. 5, A 3, from tool No. 4–3.
Card No. 6, B 3, from tool No. 1–3, which was re-treated after the selective test had been completed. The top of the tool was ground off and polished for etching. The photomicrographs were made to determine the differences in the structure of the tool steels.

When this navy yard was selected as the purchasing station for tool steels, there was no information on file as to the dimensions or amounts of the several kinds of tool steels which would be needed by the navy yards per annum. Tool steels were, therefore, purchased under the specifications given in Appendix A from time to time as required. This method necessitated advertising for bids at intervals and caused delays in delivering to a navy yard the tool steel it had ordered.

The expense of a selective test as given in Appendices C and D would be prohibitive if it were to be made to determine the award of contract for small quantities of tool steel. It was therefore decided to recommend the purchase of a six-months' supply of tool steels in order to test the specifications, given in Appendix C, to reduce to a minimum the ratio of the cost of the selective test to that of the entire amount of tool steel purchased, and to get a stock in store. Schedule 3893 was prepared for this purpose.

The selective test under Schedule 3893 indicated that only minor modifications of the specifications were necessary; and it was therefore considered safe to recommend that an annual contract for tool steels be made. The contract should be so framed that tool steels of any reasonable dimensions and in accordance with the classification of the specifications given in Appendix D, could be ordered in any desired quantities throughout a fiscal year. Schedule 4469 was prepared to meet these requirements, and an extract, which is given in Appendix E, has been made from it to explain the general scheme.

The writer wishes to acknowledge the kind assistance of Mr. Victor Johnson, of the Machinery Division, Philadelphia Navy Yard, and of the representatives of the tool steel manufacturers who observed the forging, treating and testing of the tools during the selective test of tungsten tool steel, class 1, Schedule 4469.

Appendix A.*

Specifications (47S5) for high-speed tool steel issued by the Navy Department, January 5, 1909.

1. The steel shall be made by the crucible process, and shall be of uniform quality throughout, and shall be delivered in bars of commercial length, no short bars to be received, and shall be delivered annealed unless otherwise specified. The bars shall be free from all seams, cracks, and other mechanical defects.

2. The steel shall be delivered and inspected in lots of not more than 5,000 pounds, unless otherwise specified, each lot containing its proper proportion of the sizes called for on the requisition.

3. The inspection shall be made at the Navy Yard, League Island, Pa., and shall be under the direction of an officer detailed for that duty by the Commandant of the yard.

4. Each bar, up to and including a sectional area of 2¼ square inches, shall be delivered with a test piece on one end about one and one-half times the larger dimension of the bar in length, nicked one-quarter through from each side while bar was hot, so that the test piece may be easily broken off. Larger bars to have coupon test piece forged on one end and nicked as stated above. The test piece must be stamped to match the number of the bar, and when forged down as a coupon must be about 1 inch by 1½ inches and about 3 inches long.

5. The test piece from each bar will be broken off and subjected to a high-heat test in an approved furnace, kept at a definite uniform temperature, which shall be as high as practicable. The test piece, when broken off the end of the bar, should show the fine grain which is characteristic of this class of high-speed tool steel when properly made.

High-heat test.

6. The test piece shall be preheated slowly and thoroughly in a preheating furnace kept at a uniform temperature of about 1,550 degrees F. When thoroughly heated the test piece shall be quickly transferred to the

* Appendices A, B, C, D, and F are reproductions of specifications issued by the Navy Department.

high-heat furnace and rapidly heated to just below the melting point, then promptly removed from the furnace and blown cold in a heavy blast of air.

7. Each test piece shall then have ground off one end by wet emery grinder an amount at least equal to one-half the thickness of the test piece, leaving the end after grinding a V-shape. This V-end shall then test "file hard." Each bar failing in this test shall be rejected and another bar furnished in its stead by the contractors, and failure of ten per cent. of the bars in any lot to meet this test shall reject that lot.

8. Chemical analyses shall be taken and the steel of each lot shall show the following maximum and minimum limits for the elements named:

	Not less than— *Per cent.*	Not more than— *Per cent.*
Tungsten	18.50	19.50
Chromium	5.25	6.00
Vanadium	.10	.35
Carbon	.55	.75
Manganese	...	.15
Silicon	...	.110
Phosphorus	...	.020
Sulphur	...	.020

There shall be no other impurities or ingredients, except iron, particularly no molybdenum.

9. From each lot of tool steel one or more tools shall be forged and treated with the standard high-heat treatment and ground to a uniform standard shape of cutting edge for lathe tools; these tools shall be given a standard twenty-minute test on a steel forging of the following chemical and physical characteristics, viz., to be open-hearth, either nickel or carbon steel, annealed:

Minimum tensile strength, 80,000 pounds.

Minimum elastic limit, 50,000 pounds.

Minimum elongation in 2 inches (cold bend about an inner diameter of 1 inch through 180 degrees), 25 per cent.

Maximum phosphorus, 0.06 per cent.

Maximum sulphur, 0.04 per cent.

The lathe tool, known as the standard ⅞-inch tool, shall be able to take a cut of 3/16-inch depth, with 1/16-inch feed, at surface speed of 60 feet per minute.

Copies of the above specifications can be obtained upon application to the various Navy pay officers or to the Bureau of Supplies and Accounts, Navy Department, Washington, D. C.

References: Department's order, dated December 12, 1908; S. and A. 73975.

SPECIFICATIONS FOR CARBON TOOL STEEL.

Grade "A."

Tool steel of this grade is to be used for the following purposes: Finishing tools, special machine cutting tools, etc. Grade "A" tool steel shall have a chemical composition approximately as follows:

	Per cent.		*Per cent.*
Carbon	1.10	to	1.25
Silicon	.20	to	.30
Manganese	.20	to	.30
Phosphorus, not more than	.015		
Sulphur, not more than	.015		
Tungsten, as desired, but not to exceed	3.00		
Vanadium, as desired.			

Physical Tests.—Samples submitted shall be made up into a standard ¾ by 1⅛-inch round nose roughing tool, and with a depth of cut of 3/16 inch, 1/16-inch feed, shall cut at the rate of 15 feet per minute for 20 minutes without serious injury to the nose of the tool. After redressing and grinding, the cutting speed shall be increased to 30 feet per minute, the depth of cut reduced to ⅛ inch and feed to 1/32 inch. The tool shall stand up 20 minutes under this cut. The above test should be carried on a steel cylindrical forging of the same physical character as called for under the high-speed tool steel test above.

Grade "B."

For taps, milling cutters, drills, forming tools, threading tools, threading dies, punches, etc.

Grade "B" tool steel shall have a chemical composition approximately as follows:

	Per cent.		*Per cent.*
Carbon	.90	to	1.00
Silicon	.20	to	.25
Manganese	.20	to	.25
Phosphorus, not more than	.020		
Sulphur, not more than	.025		
Vanadium, as desired.			

Physical Test.—End milling cutter shall be made up from 1-inch, selected-at-random bars and be tested on mild steel, the cut to be ¾ of an inch wide and 1/16 of an inch in depth; at the rate of 85 revolutions per minute the cutter shall travel not less than 30 inches without serious injury to the blade. The second trial shall then be made with the same cut as above at the rate of 150 revolutions per minute. The cutters shall travel at least 15 inches. Hand taps shall be made up from ½-inch bar and tested on 7/16-inch grade "A" tool steel, oil hardened, and the taps shall thread cleanly at least three holes. Quarter-inch screw dies shall be tested on drill rod steel and at 150 revolutions per minute shall cut 36 inches.

Grade "C."

For chisels, for hot and cold work, rivet punches, die blocks, shear blades, structural work, blacksmith's tools, hand bars, etc.

Grade "C" tool steel shall have a chemical composition approximately as follows:

	Per cent.
Carbon, not less than	.90
Silicon, not less than	.15
Manganese, not less than	.15
Phosphorus, not more than	.030
Sulphur, not more than	.030

Physical Tests.—Samples submitted under Grade "C" shall be made up into machine chisels, structural steel punches, and flat drills. The chisels (side cutting type) shall be tested on mild steel plates ¾ inch thick, the depth of cut to be ⅛ inch, and the length of cut shall in no case be less than 9 feet. Samples shall be taken at random from the chipping blanks and made up into cape chisels and shall be tested on nickel steel plates 2 inches in thickness and shall cut through the plate for a distance of at least 3 inches without serious injury to the chisel. The structural steel punches, ⅜ inch in diameter, shall be tested on mild steel plates 5/16

inch thick, and they shall punch not less than 600 holes at the rate of 60 holes per minute.

The flat drills, 1 inch in size, cutting on ⅞-inch nickel steel at the rate of 74 revolutions per minute, shall drill at least one hole within a time limit of three minutes.

Determination of carbon in all cases by the combustion method.

All of the above steel shall be made by the crucible process and in each grade shall be of uniform quality throughout, to be straight and true to form and size.

No cutting compounds, water or lubricants are to be used in testing the tools as above, and all tools must be in good condition at the end of the test, and in order to insure acceptance of the lot. Tools of similar type made up from materials submitted by the successful bidder shall be identical in all dimensions.

Deliveries of 30 per cent. of each size in each grade of carbon tool steel shall be made within 30 days, and such additional quantities of each size in each grade as may be ordered by the General Storekeeper within 90 days after date of order.

Appendix B.

SPECIFICATIONS FOR HIGH-SPEED TOOL STEEL, FOR U. S. NAVAL ACADEMY. SCHEDULE 3244.

Chemical Composition.

	Not less than— *Per cent.*	Not more than— *Per cent.*
Tungsten	16.00	20.00
Chromium	3.00	6.00
Carbon	.55	.75
Vanadium	...	1.00
Manganese	...	.20
Silicon	...	.25
Phosphorus	...	.020
Sulphur	...	.020
Iron		Remainder.

The tool steel shall be made in either the electric or crucible furnace. The bars must be forged accurately to the dimensions specified, free from seams, checks, or other physical defects and be of homogeneous composition. The bars will be delivered in commercial lengths, but bars shorter than 8 feet will not be accepted.

The tool steel shall be delivered in one shipment. Bars will be selected at random from the shipment, forged into test tools and tested as described below. Samples will be taken for chemical analysis. If these test tools do not show results at least equal to the sample bar tools it shall be considered sufficient cause for rejection of the entire shipment, and the contractor shall replace the shipment within two weeks after receipt of notice of rejection.

Tests.—The test tool will have a section of ¾ by 1½ inches, and will be forged and ground in the form of the No. 30 lathe tool of the Sellers system of tool forms. Each tool will be tested on a nickel-steel forging of about 100,000 pounds tensile strength, with a cut ¼ inch deep, 1/16 inch feed, and cutting speed of 45 feet per minute. The tool will be twice reground and retested. A record will be made of the length of time the tool cuts before it is ruined. This test may be modified at the discretion of the engineer officer.

Bids.—Prior to the time fixed for opening the bids each bidder must submit a sample bar of the steel he proposes to furnish, to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa.

Samples delivered late will not be received and the bids will not be considered.

The bidder will determine the exact composition for the sample bar, but it must be within the limits specified. If, however, the bidder wishes to submit more than one sample of a composition between the limits specified, provided each bar is of different composition, he may do so. The sample bars must be ¾ by 1½ inches section by 6 feet long. Each sample bar will be marked to correspond with the bid. These bars will be forged into 5 tools and tested as specified above.

Each bidder shall inform the Engineer Officer, Navy Yard, Philadelphia, Pa., of the exact chemical composition of the sample bar or bars delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., and he will state in detail the treatment to which the test tools must be subjected in order to get, in his opinion, the best results. This information will be considered confidential.

All bids and sample bars to be referred to the Engineer Officer, Navy Yard, Philadelphia, Pa., for him to make the tests outlined above and to recommend the award of contract for the steel which, in his opinion, is best suited for the purpose, due consideration being given to cost.

General.—Bids on tool steel differing from the above chemical composition will be considered, provided the material is suitable for the purpose intended. A statement of the chemical composition as outlined above will be required.

Failure to comply with all requirements will render the bid liable to rejection.

All descriptive matter modifying the above specifications must be in duplicate, labeled with the above class number and pasted or otherwise attached to this page of the proposal in both the original and duplicate bids. Detailed specifications, in duplicate, stating specifically wherein the article proposed does not conform to the above specifications must also be submitted.

Appendix C.

Specifications (4735) for tool steel issued by the Navy Department July 20, 1911.

(Superseding "Specifications 47S5," issued January 5, 1909.)

Chemical Composition.

Tungsten steel.	Class 1.	Class 2.
	Per cent. limit.	Per cent. limit.
Carbon	0.75 to 0.55	1.50 to 1.35
Chromium	5.00 to 2.50	Optional.
Manganese	.30 to .05	.20 to .10
Phosphorus	.015 to .00	.015 to .00
Silicon	.30 to .00	.20 to .00
Sulphur	.02 to .00	.02 to .00
Tungsten	20.00 to 16.00	5.00 to 2.00
Vanadium	... to .35	Optional.
Iron	Remainder.	Remainder.

Carbon steel.	Class 1.	Class 2.	Class 3.	Class 4.
	Per ct. limit.	Per ct. limit.	Per ct. limit.	Per ct. limit.
Carbon	1.25 to 1.25	1.15 to 1.05	0.95 to 0.85	0.85 to 0.75
Chromium	Optional.	Optional.	Optional.	Optional.
Manganese	.35 to .15	.35 to .15	.35 to .15	.35 to .15
Phosphorus	.015 to .00	.015 to .00	.02 to .00	.02 to .00
Silicon	.40 to .10	.40 to .10	.40 to .10	.40 to .10
Sulphur	.02 to .00	.02 to .00	.02 to .00	.025 to .00
Vanadium	Optional.	Optional.	Optional.	Optional.
Iron	Remainder.	Remainder.	Remainder.	Remainder.

1. Method of manufacture and physical requirements.—The tool steel shall be made in either the electric or crucible furnace. The bars must be forged or rolled accurately to the dimensions specified; to be free from seams, checks, and other physical defects and be of homogeneous composition. The tungsten steels will be delivered unannealed unless otherwise specified, and the carbon steels will be delivered annealed unless otherwise specified. The bars will be delivered in commercial lengths and short pieces will not be accepted unless so specified.

2. Stamps on material.—The contractor shall stamp on each bar or piece of steel his name, his trade name of the steel which he is furnishing, and the kind of steel and class as given in these specifications. If the bars are longer than about 3 feet the above stamps will be placed at intervals of about 3 feet along the bar.

3. Delivery of material.—All material will be delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa. Lots of material less than 1,000 pounds will be delivered in one shipment, and in general all material will be delivered in one shipment if practicable.

4. Acceptance test.—Samples for acceptance test will be taken from the material delivered to the General Storekeeper, Navy Yard, Philadelphia, Pa., or if the material is inspected at the place of manufacture, the inspector of engineering material will forward samples as called for under the heading "samples furnished by bidder" to the General Storekeeper, Navy Yard, Philadelphia, Pa., who will forward them to the engineer officer. The engineer officer will arrange for the tests, both chemical and physical, required by these specifications and recommend the acceptance or rejection of the material.

5. Rejection.—If the material is not equivalent to the sample furnished with bid it will be considered sufficient cause for rejection. The contractor shall replace the shipment within two weeks, if practicable, after the receipt of notice of rejection.

PHYSICAL TESTS.

Tungsten Steel.

6. Class 1.—The sample bar will be forged into 5 tools, treated and ground to the No. 30 form of the Sellers system of tool forms. Each tool will be tested on nickel-steel forging of about 100,000 pounds tensile strength, with a cut ¼ inch deep, 1/16 inch feed, and a cutting speed of 50 feet per minute. The tool will be twice reground and retested. A record will be made of the length of time the tool cuts without a lubricant or cutting compound before it is ruined.

7. *From the sample bar, 3⅜ inches round, 2 butt mills, 3⅛ inches diameter, will be made and tested on a nickel-steel block, with cut 0.20

inch deep, 1¼ inches wide, feed 0.04 inch per revolution of mill, at a speed of 100 feet per minute. Each mill to run at least 40 inches and be in fair condition at end of run. Lubricant to be used.

8. Class 2.—The bar will be forged into 5 tools, treated and ground to the No. 22 form of Sellers system of tool forms. Each tool will be tested on a carbon open-hearth steel forging of about 60,000 pounds tensile strength, with a cut 1/32 inch deep, ⅛ inch feed, and a cutting speed of about 50 feet per minute. A record will be made of the length of time the tool cuts with a lubricant or cutting compound before it is ruined.

9. *From the ¾ by 1½-inch sample bar, 3 standard round-nose roughing tools will be made and tested on nickel-steel forging, with a ¼-inch cut; feed 0.05 inch per revolution, and a speed of 15 feet per minute. Each tool should run for 20 minutes without serious injury without a lubricant.

Carbon Steel.

10. Class 1.—Machinists' taps, ⅜-inch diameter, will be made and tested on nickel steel. A record will be made of the number of holes tapped before the tap is ruined. A lubricant will be used, and the revolutions per minute of the tap will be varied to suit conditions.

11. *From the 2½-inch square sample bar 3 finishing tools will be made and tested on a nickel-steel forging, with a cut from 0.001 to 0.003 inch deep, a feed 2¼ inches per revolution, and a speed of 8 feet per minute. Each tool should make a clean, smooth finish for a run of at least 20 feet without lubrication.

12. Class 2.—One 1-inch end mill will be made and tested with a lubricant by cutting a piece of class 4 carbon steel. The depth of cut will be 1/16 inch, the revolutions per minute will be varied to suit conditions, and a record will be made of the length of time the mill cuts before it is ruined.

13. *From the sample bar, 1⅜ inches round, one end mill, 1¼ inches diameter, will be made and tested on a mild-steel block, cut 0.20 inch deep, 0.50 inch wide; feed 0.018 inch per revolution; at a speed of 40 feet per minute. The mill should run at least 40 inches and be in fair condition at the end of run. Lubricant to be used.

14. Class 3.—Pneumatic cape chisels, ½-inch, will be made and tested with a lubricant on nickel steel. A record will be made of the distance the tool cuts before it is ruined.

15. Class 4.—Rivet sets, ½-inch, will be made and tested, and a record will be made of the number of rivets the set will drive before it is ruined.

16. Modification of tests.—Any or all the above tests may be modified at the discretion of the engineer officer.

17. Samples furnished by bidders.—Each bidder shall furnish with his bid one bar of steel as follows:

Tungsten—
- Class 1.—¾ by 1½ inches by 5 feet long.
- *Class 1.—3⅜ inches round by 24 inches long.
- Class 2.—¾ by 1½ inches by 5 feet long.

Carbon—
- Class 1.—½-inch diameter rod, 2 feet long.
- *Class 1.—2½ inches square by 6 feet long.
- Class 2.—1¼-inch diameter rod, 2 feet long.
- *Class 2.—1⅜ inches round, 24 inches long.
- Class 3.—¾-inch octagon rod, 5 feet long.
- Class 4.—2-inch diameter rod, 2 feet long.

18. All samples must be delivered (unless otherwise specified in the proposal) to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., prior to the time fixed for opening the bids. Failure to comply with this requirement will eliminate the bid from consideration.

The sample bar will be delivered by the general storekeeper to the engineer officer for him to direct the selective tests.

Samples delivered late will not be received and the bids will not be considered.

19. *The requirements indicated by asterisk apply only to tool steel required for delivery to the Navy Yard, Washington, D. C.

20. Treatment of samples.—Each bidder must state in his bid the treatment to which the material is to be subjected in order to get, in his opinion, the best results.

21. Recommendation of award.—The right is reserved to reject any or all bids. Failure to comply with all the requirements will eliminate the bid from consideration.

22. The engineer officer will, after the prescribed tests have been made, recommend the award for contract for the steel or steels which, in his opinion, it is to the best interest of the government to purchase, due consideration being given to the cost of the material. The relation of the physical test and the price of the material will be the basis for selection.

23. Alternate proposals.—Bidders may submit proposals on steel which differs from the composition specified, provided this is clearly stated in their bids, and provided they furnish the engineer officer with the exact chemical composition of the material. This information will be considered confidential by the engineer officer if the bidder request it. The material will be tested if, in the opinion of the engineer officer, it is considered suitable for the purpose intended.

24. Defective material.—If material, when being manufactured into tools, develops physical defects which could not be detected by inspection, such as "cracks," "pipes," etc., the manufacturer of this steel shall replace, without cost to the government, such defective material.

PURPOSE FOR WHICH THE STEEL IS INTENDED.

Tungsten Steel.

25. Class 1.—Lathe and planer tools, milling-machine tools, etc., and in general all tools for which high-speed steel is used.

26. Class 2.—Lathe and planer tools, and in general tools for finishing purposes, either steel or brass.

Carbon Steel.

27. Class 1.—Lathe and planer tools, drills, taps, reamers, screw-cutting dies, taps, and tools requiring keen cutting edge combined with great hardness.

28. Class 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine-shop tools requiring a keen cutting edge combined with hardness.

29. Class 3.—Pneumatic chisels, punches, shear blades, etc., and in general tools requiring hard surface with considerable tenacity.

30. Class 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop forge dies, etc., and in general tools which require great toughness combined with the necessary hardness.

Copies of the above specifications can be obtained upon application to the various Navy pay officers or to the Bureau of Supplies and Accounts, Navy Department, Washington, D. C.

References: Department's order, Dec. 12, 1908; Tool Steel Board, June 7, 1911; Dept., 25164-200f., June 8, 1911; Bu. C. and R., 2328-A. 104, June 13, 1911; S. and A., 73975, 85744, and 104054.

APPENDIX D.

SPECIFICATIONS FOR SCHEDULE 4469.
PURPOSE FOR WHICH THE STEEL IS INTENDED.

Tungsten Tool Steel.

1. Class 1.—Lathe and planer tools, milling-machine tools, and in general all tools for which high-speed steel is used.

Carbon Tool Steel.

2. Class 1.—Lathe and planer tools, and tools requiring keen cutting edge combined with great hardness, for finishing shrinkage dimensions on nickel-steel gun forgings, drills, taps, reamers, and screw-cutting dies.

3. Class 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine-shop tools requiring a keen cutting edge combined with hardness.

4. Class 3.—Pneumatic chisels, punches, shear blades, etc., and in general tools requiring hard surface with considerable tenacity.

5. Class 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop forge dies, etc., and in general tools which require great toughness combined with the necessary hardness.

Chemical Composition.

Tungsten tool steel.	Class 1, per cent. limit. Maximum.	Minimum.
Carbon	0.75	0.55
Chromium	5.00	2.50
Manganese	.30	.05
Phosphorus	.015	.00
Silicon	.30	.00
Sulphur	.02	.00
Tungsten	20.00	16.00
Vanadium	1.50	.35
Iron	Remainder.	Remainder.

Carbon tool steel.	Per cent. limit. Class 1.		Class 2.		Class 3.		Class 4.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Carbon	1.25	1.15	1.15	1.05	0.95	0.85	0.85	0.75
Chromium	†	†	†	†	†	†	†	†
Manganese	.35	.15	.35	.15	.35	.15	.35	.15
Phosphorus	.015	.00	.015	.00	.02	.00	.02	.00
Silicon	.40	.10	.40	.10	.40	.10	.40	.10
Sulphur	.02	.00	.02	.00	.02	.00	.025	.00
Vanadium	†	†	†	†	†	†	†	†
Iron	*	*	*	*	*	*	*	*

* Remainder. † Optional.

PHYSICAL TESTS.

Tungsten Tool Steel.

6. Class 1.—The sample bar will be forged into 5 tools, treated and ground to the No. 30 form of the Sellers system of lathe tool forms. Each tool will be tested on a nickel-steel forging of about 100,000 pounds

tensile strength, with a cut ¼ inch deep, 1/16 inch feed, and a cutting speed of 50 feet per minute. Each tool will be twice reground and retested. A record will be made of the length of time each tool cuts without a lubricant or cutting compound before it is ruined.

Carbon Tool Steel.

7. Class 1.—Five 7/16-inch diameter, 4-tooth facing mills will be made from the sample bar and tested on a piece of ⅝-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

8. Class 2.—Five 7/16-inch diameter, 4-tooth facing mills will be made from the sample bar and tested on a piece of ⅝-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

9. Class 3.—Five ½-inch pneumatic chisels will be made from the sample bar. Each chisel will be tested on a nickel-steel plate with a cut 1/16 inch deep.

A record will be made of the distance each chisel cuts with a lubricant before it is ruined.

10. Class 4.—Two ½-inch rivet sets will be made from the sample bar. A record will be made of the condition of the sets after a certain number of rivets have been driven.

11. Modification of tests.—Any or all of the above tests may be modified at the discretion of the engineer officer.

General.

12. Method of manufacture.—The tool steels shall be made in either the electric or crucible furnace. The bars must be forged or rolled accurately to the dimensions specified, free from seams, checks, and other physical defects and of homogeneous composition. The tungsten tool steels shall be delivered unannealed, unless otherwise specified, and the carbon tool steels shall be delivered annealed unless otherwise specified. The bars shall be delivered in commercial lengths and short pieces will not be accepted unless so specified.

13. Stamps on material.—Each bar or piece of tool steel, whether sample bar for "selective test," "acceptance test," or material delivered under contract, shall be stamped with the manufacturer's name, his trade name and temper index, and in addition identification stamps of the kind and class of tool steel as given in these specifications. The tungsten tool steel, class 1, shall be stamped T–1, and the carbon tool steels, classes 1, 2, 3, and 4: C–1, C–2, C–3, and C–4. The letters to be about 3/16 inch high. If the bars are longer than about 4 feet, the above stamps should be placed at intervals of about 3 feet along the bar.

14. Acceptance test.—Sample bars for "acceptance test" will be taken from the material delivered under contract to the General Storekeeper, Navy Yard, Philadelphia, Pa., or if the material is inspected at the place of manufacture, the inspector will forward sample bars of the dimensions called for to the General Storekeeper, Navy Yard, Philadelphia, Pa., who will forward them to the engineer officer for him to arrange the tests indicated by these specifications and recommend the acceptance or rejection of the material. If the material proves to be not equivalent to the sample bar furnished with proposal this will be considered sufficient cause

for rejection. The contractor shall replace the shipment within two weeks, if practicable, after the receipt of notice of rejection. The sample bars used for this test will be credited the contractor if the material under test is accepted.

15. Defective material.—If material, when being manufactured into tools develops physical defects which could not be detected by inspection, such as "cracks," "pipes," etc., the manufacturer of this steel shall replace, without cost to the government, such defective material.

Proposals.

16. Reservation and alternate proposals.—The right is reserved to reject any or all proposals.

Bidders may submit proposals on tool steel which differs from the composition and method of manufacture specified, provided this is clearly stated in their proposal, and provided they furnish the engineer officer with a statement of the exact chemical composition and method of manufacture of the tool steel. This information will be considered confidential by the engineer officer if the bidder requests it. The tool steel will be tested if, in the opinion of the engineer officer, it is considered suitable for the purpose intended.

17. The engineer officer will, after the prescribed tests have been made, recommend the award of contract for the steel or steels which, in his opinion, it is to the best interest of the government to purchase, due consideration being given to the cost of the material. The relation of the tests and the price of the material will be the basis for selection.

18. Selective test.—Each bidder shall furnish with his proposal a sample bar of tool steel stamped as called for under heading "Stamps on material" for the "selective test." The relation of the results obtained from the tests conducted as provided for under the heading "Physical tests" and the price of the material determine the selective factor. The dimensions of the sample bars shall be as follows:

Tungsten tool steel—

Class 1.—¾ by 1½ inches by 5 feet long.

Carbon tool steel—

Class 1.—⅝-inch diameter rod, 2 feet long.

Class 2.—⅝-inch diameter rod, 2 feet long.

Class 3.—¾-inch octagon rod, 5 feet long.

Class 4.—2-inch diameter rod, 2 feet long.

19. Treatment of samples.—Each bidder will state in his proposal, if he considers it necessary to do so, the treatment to which the material must be subjected in order to get, in his opinion, the best results.

20. Delivery of sample bars.—All sample bars stamped as called for under the heading "Stamps on material" must be delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., prior to the time fixed for opening of proposals. Sample bars delivered late will not be received. Failure to comply with the above requirements will eliminate the proposal from consideration. All sample bars will be delivered by the general storekeeper to the engineer officer for him to conduct the "selective tests."

APPENDIX E.

EXTRACT FROM SCHEDULE 4469.

No. of item.	Articles.	Unit price.		Total.	
		Dollars.	Cents.	Dollars.	Cents.
	CLASS 21.—(Request No. 229, G. A. A., Naval Supply Account, C. and R. and S. E.—Philadelphia, Pa.—Sch. 4469.)				
	To be delivered at the navy yard, Philadelphia, Pa., during the fiscal year ending June 30, 1913, as may be required (no single order to be for less than 1,000 pounds, except with the consent of the contractor), within 30 days after date of receipt of order from the general storekeeper. If unable to make delivery within the time specified, state actual number of days required, bureau reserving right to make award on time stated above.				
	STOCK CLASSIFICATION NO. 46.				
	Tungsten tool steel, class 1, round, square, octagon, or hexagon, as may be required, as follows:				
	Annealed—				
1	200 pounds (about) $\frac{5}{8}$ to 2 inches, inclusive ....per pound				
2	100 pounds (about) 2$\frac{1}{4}$ to 3 inches, inclusive ....per pound				
3	100 pounds (about) 3$\frac{1}{4}$ to 4 inches, inclusive .....per pound				
	* * * * * * * *				
99	100 pounds (about) 3$\frac{1}{4}$ to 4 by 6$\frac{1}{2}$ to 8 inches, inclusive....per pound				
100	100 pounds (about) 4$\frac{1}{4}$ to 5 by 4$\frac{1}{2}$ to 7 inches, inclusive ...per pound				
101	100 pounds (about) 4$\frac{1}{4}$ to 5 by 7$\frac{1}{2}$ to 8 inches, inclusive....per pound				
102	100 pounds (about) 5$\frac{1}{2}$ to 6 by 5$\frac{1}{2}$ to 8 inches, inclusive....per pound				
103	100 pounds (about) 6$\frac{1}{2}$ to 7 by 6$\frac{1}{2}$ to 7 inches, inclusive....per pound				
104	100 pounds (about) 6$\frac{1}{2}$ to 8 by 7$\frac{1}{2}$ to 8 inches, inclusive....per pound				
	Intermediate sizes not specified, when required, will be ordered and paid for at the price of the next higher size. For specification, see page 1 of this schedule. (Appendix D.) As the bureau is unable to state definitely the exact quantities of the above material that will be used, the quantities stated above for each item are estimated only and are merely for the information of bidders in preparing bids. It shall be distinctly understood and agreed that it is the intention of the contract that the contractor shall furnish and deliver any quantities of all the above-mentioned material which may be needed for the naval service at the place named during the fiscal year ending June 30, 1913, irrespective of the estimated quantity for each item named above. All bids to be referred to the department.				
	Total Class 21.....				

Appendix F.

Tool steel specifications.*

Purpose for which the steel is intended.

Tungsten Tool Steel.

1. Class 1.—Drill rods, lathe and planer tools, milling-machine tools, and in general all tools for which high-speed steel is used.
2. Class 2.—Lathe and planer tools and general machine shop tools which require a keen and *durable* cutting edge.

Carbon Tool Steel.

3. Class 1.—Drill rods, lathe and planer tools, and tools requiring keen cutting edge combined with great hardness, such as drills, taps, reamers, and screw-cutting dies.
4. Class 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine-shop tools requiring a keen cutting edge combined with hardness.
5. Class 3.—Pneumatic chisels, punches, shear blades, etc., and in general tools requiring hard surface with considerable tenacity.
6. Class 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop-forge dies, etc., and in general tools which require great toughness combined with the necessary hardness.

* Specifications to govern the purchase of tool steel for the fiscal year beginning July 1, 1913.

Chemical Composition.

Tungsten tool steel.	Per cent. limit. Class 1.		Per cent. limit. Class 2.	
	Max.	Min.	Max.	Min.
Carbon	0.75	0.55	1.50	1.35
Chromium	5.00	2.50	.00	.00
Manganese	.30	.05	.20	.10
Phosphorus	.015	.00	.015	.00
Silicon	.30	.00	.20	.00
Sulphur	.02	.00	.02	.00
Tungsten	20.00	16.00	3.50	2.00
Vanadium	1.50	.35	†	†
Iron	*	*	*	*

Carbon tool steel.	Per cent. limit. Class 1.		Class 2.		Class 3.		Class 4.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Carbon	1.25	1.15	1.15	1.05	0.95	0.85	0.85	0.75
Manganese	.35	.15	.35	.15	.35	.15	.35	.15
Phosphorus	.015	.00	.015	.00	.02	.00	.02	.00
Silicon	.40	.10	.40	.10	.40	.10	.40	.10
Sulphur	.02	.00	.02	.00	.02	.00	.025	.00
Tungsten	.00	.00	.00	.00	†	†	.00	.00
Iron	*	*	*	*	*	*	*	*

*Remainder. †Optional.

PHYSICAL TESTS.

Tungsten Tool Steel.

7. Class 1.—The sample bar will be forged into 5 tools, treated and ground to the No. 30 form of the Sellers system of lathe-tool forms. Each tool will be tested on a nickel-steel forging of about 100,000 pounds tensile strength, with a cut 3/16 inch deep, 0.044 inch feed, and a cutting speed of 65 feet per minute. Each tool will be twice reground and retested. A record will be made of the length of time each tool cuts without a lubricant or cutting compound before it is ruined.

8. Class 2.—Five 7/16-inch diameter, 4-tooth facing mills will be made from the sample rod and tested on a piece of ⅝-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

Carbon Tool Steel.

9. Class 1.—Five 7/16-inch diameter, 4-tooth facing mills will be made from the sample rod and tested on a piece of ⅝-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

10. Class 2.—Five 7/16-inch diameter, 4-tooth facing mills will be made from the sample rod and tested on a piece of ⅝-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

11. Class 3.—Five ½-inch pneumatic chisels will be made from the sample bar. Each chisel will be tested on a nickel-steel plate with a cut 1/16 inch deep. A record will be made of the distance each chisel cuts with a lubricant before it is ruined.

12. Class 4.—Two ½-inch rivet sets will be made from the sample bar. A record will be made of the condition of the sets after a certain number of rivets have been driven.

13. *Modification of tests.*—Any or all of the above tests may be modified at the discretion of the engineer officer.

General.

14. *Method of manufacture.*—The tool steels must be made in either the electric or crucible furnace, and must be of homogeneous composition. The bars or rods shall be forged or rolled accurately to the dimensions specified, and must be free from seams, checks, and other physical defects. They must be delivered *annealed* and, unless otherwise specified, in commercial lengths. Short pieces will not be accepted. Drill rods must be coated with a rust preventive.

15. *Stamps on material.—Each bar or rod of tool steel, excepting drill rods, whether sample for "selective test," or material delivered under contract, shall be legibly stamped with the manufacturer's name, his trade name, heat number and temper index of the tool steel, also the classification stamps as given in these specifications.* The tungsten tool steels, Classes 1 and 2, shall be stamped T-1 and T-2, respectively, and the carbon tool steels, Classes 1, 2, 3 and 4: C-1, C-2, C-3 and C-4, respectively. The letters and figures of these classification stamps should be about 3/16

inch high. If the bars or rods are longer than about 4 feet and larger than ⅜ inch diameter, square, hexagon, octagon, etc., the above stamps should be placed at intervals of about 3 feet along the bar. On bars ⅜ inch diameter, square, hexagon, octagon, etc., and smaller, the above stamps should be placed on one end only. Each drill rod shall be stamped with the tool steel classification stamp only, and only on one end.

16. *Acceptance Test.*—Samples for chemical analyses for "acceptance test" will be taken from the material delivered by the contractor to the General Storekeeper, Navy Yard, Philadelphia, Pa., or if the material is inspected at place of manufacture, the inspector will forward samples for chemical analyses to the General Storekeeper, Navy Yard, Philadelphia, Pa., who will forward them to the Engineer Officer, for him to arrange for the analyses and recommend the acceptance or rejection of the material. *If the analysis proves that the composition of the material does not correspond to that of the sample bar or rod submitted for "selective test," or if the sulphur or phosphorus content exceeds the specification limits, the material will be rejected.* Physical tests similar to the "selective test" may also be made, at the discretion of the engineer officer. The contractor shall replace the rejected shipment within two weeks, if practicable, after receipt of notice of rejection. The bidder must state, in his proposal, the place where the tool steel is to be manufactured, in order that arrangements can be made for inspection at place of manufacture.

17. *Defective Material.*—If material, when being manufactured into tools, develops physical defects which could not be detected by inspection, such as "cracks," "pipes," etc., the manufacturer of this steel shall replace, without cost to the Government, such defective material.

Proposals.

18. *Reservation and Alternate Proposals.*—The right is reserved to reject any or all proposals.

Bidders may submit proposals on tool steel which differs from the composition and method of manufacture specified, *provided this is clearly stated in their proposal, and provided they furnish the Engineer Officer with a statement of the exact chemical composition and method of manufacture of the tool steel.* This information will be considered confidential by the Engineer Officer if the bidder requests it. The tool steel will be tested if, in the opinion of the Engineer Officer, it is considered suitable for the purpose intended.

19. *Selective Test.*—Each bidder shall submit with his proposal sample bars of tool steel stamped as called for under heading "Stamps on Material" for the "selective test." The relation of the results obtained from the tests conducted as provided for under the heading "Physical tests" and the price of the material determines the selective factor. The dimensions of the sample bars shall be as follows:

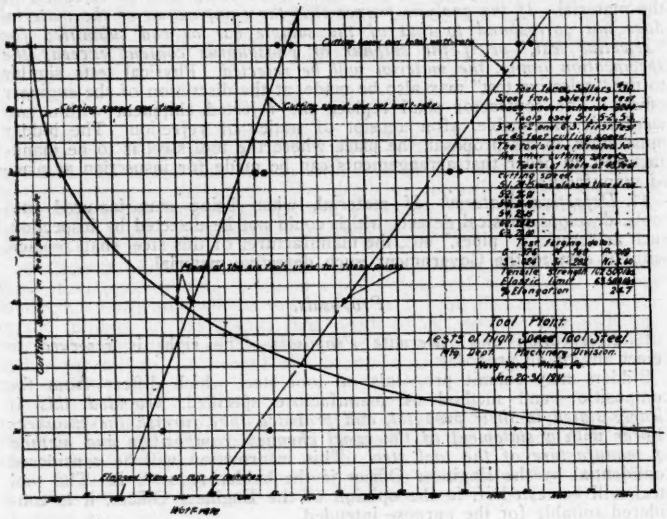
Tungsten tool steel:
Class 1.—½ by 1 inch by 5 feet long.
Class 2.—11/16 inch diameter rod, 2½ feet long.
Carbon tool steel:
Class 1.—11/16 inch diameter rod, 2½ feet long.
Class 2.—11/16 inch diameter rod, 2½ feet long.
Class 3.—¾ inch octagon rod, 5 feet long.
Class 4.—2 inch diameter rod, 2 feet long.

20. *Treatment of Samples.*—Each bidder will state in his proposal, if he considers it necessary to do so, the treatment to which the material must be subjected in order to get, in his opinion, the best results.

21. *Delivery of Sample Bars.*—All sample bars stamped as called for

under the heading "Stamps on material" must be delivered to the General Storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., *prior to the time fixed for opening of proposals. Sample bars delivered late will not be received. Failure to comply with the above requirements will eliminate the proposal from consideration.* All sample bars will be delivered by the General Storekeeper to the Engineer Officer for him to conduct the "selective tests."

22. *Award of Contract.*—The engineer officer will, after the prescribed tests have been made, recommend the award of contract for the tool steel or tool steels which, in his opinion, it is to the best interest of the Government to purchase. The selective factor will be the basis for selection.


Cutting speed and feed
Cutting speed and cut
Cutting speed and tool life
Tool Plant
Tests of High Speed Tool Steel
Mfg Dept Machinery Division

No. 288.

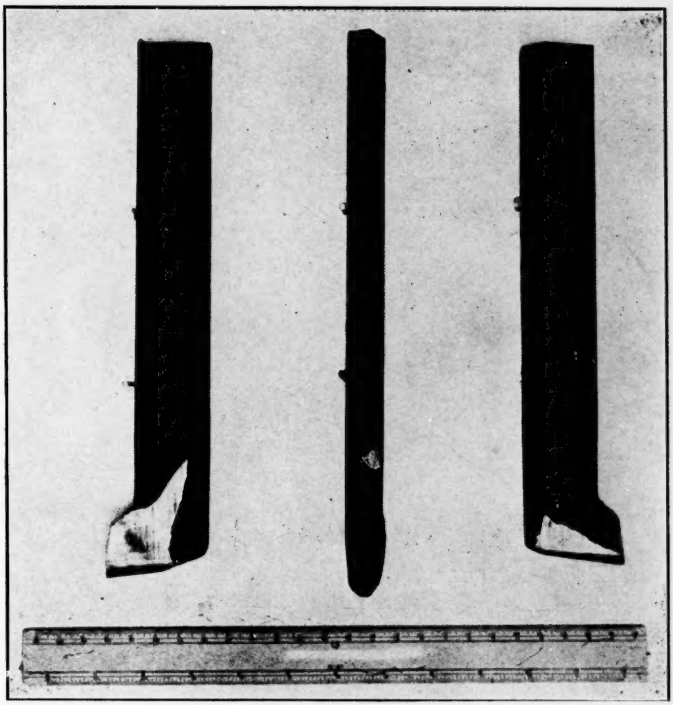


PLATE 1.

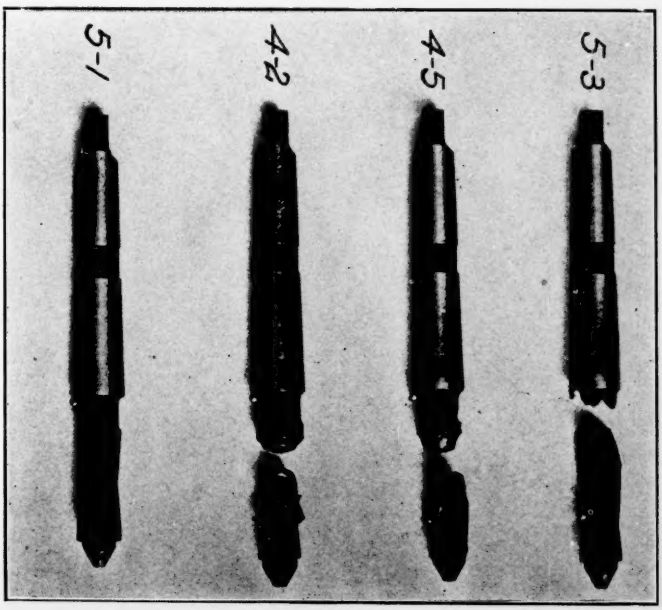
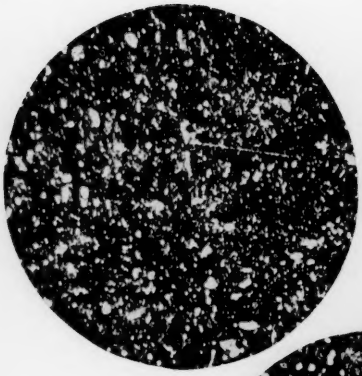


PLATE 2.



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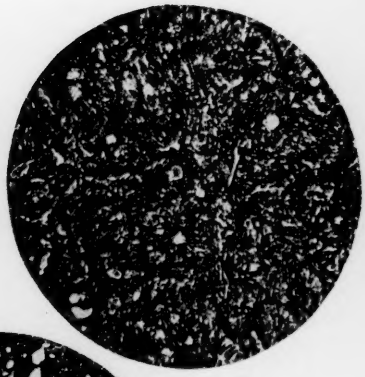

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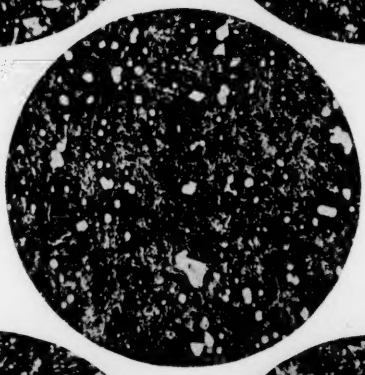

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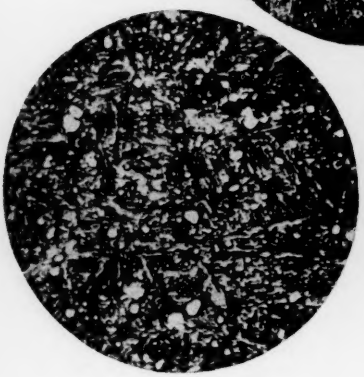

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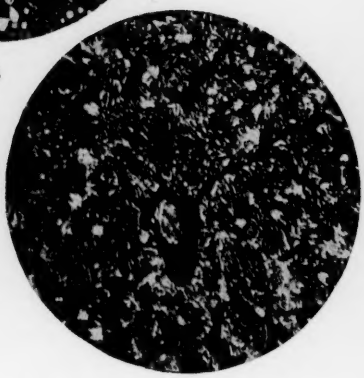


5

PLATE 3.

Fig 1.—Card No. 4, B-2, from Tool No. 1-2.
Fig. 2.—Card No. 4, B-2, from Tool No. 3-2.
Fig. 3.—Card No. 5, A-3, from Tool No. 4-3.
Fig. 4.—Card No. 6, B-3, from Tool No. 1-3.
Fig. 5.—Card No. 8, B-4, from Tool No. 2-4.

Sheet	Specification	As per Schedule 3244.																		
	Furnished by																			
	Tool Number	1-1	1-2	1-4	2-1	2-2	2-3	3-1	3-2	3-4	4-1	4-3	4-5	5-1	5-3	5-5	6-1	6-2	6-4	
Cutting Observations	1st Grinding	13.82	22.15	23.20	16.77	8.89	8.00	8.85	8.88	11.18	14.25	14.72	13.04	20.85	21.18	32.50	21.85	22.08	32.50	22
Speed, Cut per Min. Time of Run in Minutes.	1st Regrinding	13.16	17.51	17.55	12.60	18.03	11.25	8.35	6.55	7.68	21.40	11.68	13.13	13.42	17.32	18.34	16.83	24.57	18.34	12
	2nd Regrinding	15.25	16.13	10.85	7.75	5.84	7.42	5.85	6.17	2.90	30.46	15.61	15.35	17.65	26.55	17.05	15.90	21.32	17.05	12
	Mean	14.74	18.59	14.80	10.37	10.82	8.89	7.68	7.53	7.19	18.67	14.00	13.97	18.97	18.35	27.63	18.03	24.00	18.63	12
	Arithmetical Mean.	15.51			10.03			7.43			15.81			21.77			20.51			
	1st Grinding	45	44	46	45	46	46	45	45	45	46	45	45	45	45	45	45	45	45	4
	1st Regrinding	45	45	46	46	46	44	46	46	46	45	46	46	45	45	45	45	45	45	4
	2nd Regrinding	46	46	46	45	45	45	45	45	45	48	45	45	45	48	45	45	45	45	4
Cut	Mean	45.3	45.6	46	45.3	45.6	45	45.3	45.3	45.3	46.9	46	45	45	46	45	45	45	45	4
	Arithmetical Mean	45.6			45.3			45.3			45.1			45			45			
	Depth of	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/
	Feed of	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/
	Ratio of elapsed times of runs Numerator 20-51 / Denominator 20-51	1.320 / .756			2.040 / .489			2.780 / .963			1.320 / .756			.943 / 1.060			1.000 / 1.000			
Electrical Observations	Volts. Mean	3.31	3.29	3.28	3.32	3.33	3.32	3.32	3.33	3.33	3.32	3.33	3.33	3.30	3.30	3.30	3.31	3.31	3.31	3.
	Friction	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
	1st Grinding	30-33	31-33	31-33	33-36	31-33	31-33	33-36	30-33	29-31	30-33	30-32	28-30	33-36	33-36	28-30	31-33	29-31	32-34	29
	1st Regrinding	29-31	29-31	29-31	29-31	29-31	31-33	33-36	33-36	29-31	30-33	29-31	31-33	33-36	31-33	31-33	29-31	29-31	31-33	29
Amperes	2nd Regrinding	29-31	29-31	29-31	29-31	29-31	29-31	31-34	31-33	31-33	30-33	30-32	31-33	31-34	29-31	29-31	29-32	29-32	31-33	29
	Mean	29.50	29.50	29.50	29.70	31.3	31.3	33.3	32	30.3	31.1	30.3	31	33	31.5	30	31	30.3	31.5	29
Watts	Arithmetical Mean	31.8			31.2			31.9			30.9			31.5			31			
	Total	7568			7478			7504			7390			7488			7380			
	Friction	2380			2380			2380			2380			2380			2380			
	Net	5188			5098			5124			5010			5178			5000			
Hardness Scleroscope Test	Point 1	74	75	65	69	75	71	77	73	76	69	74	72	64	78	75	75	78	6	
	Point 2	70	76	72	72	74	73	77	77	77	74	74	74	78	84	79	80	78	7	
	Point 3	78	77	73	75	73	76	78	79	81	76	76	77	82	85	79	84	84	8	
	Point 4	82	80	84	80	84	82	86	85	82	74	84	86	84	84	90	80	84	8	
Furnace Observations	Treatment															1st	Treatment			
	Elapsed Time in High Heat	---	---	---	1.71	1.24	1.68	1.65	1.00	1.52	1.73	---	1.70	1.68	1.68	1.68	---	1.65	1.7	
	Pre-Heat °F	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	15	
	High Heat °F	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26
Price Deductions	Price per Pound, Cents.	42			36			41.75			35			50			45			
	Ratio (Reciprocal Value of Col. 2 Below) / Price per Pound	.369			.278			.178			.329			.375			.456			
	Ratio of Above Ratios Numerator 456 / Denominator 656	1.348 / .809			1.640 / .609			2.560 / .390			1.420 / .619			1.220 / .823			1.000 / 1.000			
	Ratio of Price per Pound Numerator 45 / Denominator 45	1.070 / .933			1.250 / .800			1.080 / .928			.818 / 1.220			.776 / 1.290			1.000 / 1.000			
	Relative value in Cents per Pound (Reciprocal Value of Price in Cents per Pound) / 20.51 (Price in Cents per Pound of Tool No. 20-51)	.341 / 555			.281 / 735			.163 / 1151			.341 / 724			.427 / 546			.45 / 45			

Notes:-

Pyrometer corrections :- Pre-Heat +280°. High Heat -325°.

Test of high speed tool steels :- to select material for the U.S. Naval Academy under schedule 3244, to compare steel furnished under specification 47-3-S, and to secure data for a curve of cutting speed and elapsed time of runs in minutes. All tools were run until ruined and no lubricant or cutting compound was used.

Specified Chemical Composition of High Speed Steel.

	Carbon	Chromium	Manganese	Phosphorus	Silicon	Sulphur	Tungsten	Vanadium
Sched. 3244	.55 to .75	3.00 to 4.00	.40 to .80	.00 to .02	.00 to .25	.00 to .02	16.00 to 20.00	.00 to 1.00
47-3-S	.65 - .75	3.25 - 3.60	.20 - .15	.00 - .02	.00 - .11	.00 - .02	18.50 - 19.00	.10 - .35

Explanation of Computations:-

"Ratio of elapsed times of runs."

Upper line = Arithmetical mean of elapsed times of runs of tools 6-1, 6-2, 6-3 = 20.51 / Arithmetical mean of elapsed times of runs of other tools.

Lower line = Arithmetical mean of elapsed times of runs of other tools. / Arithmetical mean of elapsed times of runs of tools 6-1, 6-2, 6-3 = 20.51

"Ratio of above ratios."

Upper line = Ratio of tools 6-1, 6-2, 6-3 = .456 / Ratio of other tools.

Lower line = Ratio of other tools / Ratio of tools 6-1, 6-2, 6-3 = .456

"Ratio of price per lb."

Upper line = Price of tools 6-1, 6-2, 6-3 per lb = .741 / Price of other tools per lb.

Lower line = Price of other tools per lb. / Price of tools 6-1, 6-2, 6-3 per lb = .4537

"Relative value in cents per pound."

The upper line in table shows the relative value in cents per pound of other tools compared with "price per pound, cents" of tools 6-1, 6-2, 6-3.

Price of tools 6-1, 6-2, 6-3 per lb in cents × Arith. mean of elapsed times of runs in min. of other tools / Arithmetical mean of elapsed times of runs in min. of tools 6-1, 6-2, 6-3

The lower line in table shows the relative value in cents per pound of tools 6-1 6-2, 6-3, compared with "price per pound, cents" of other tools.

Price of other tools per lb in cts. × Arith. mean of elapsed times of runs in min. of tools 6-1, 6-2, 6-3 / Arithmetical mean of elapsed times of runs in min. of other tools.

Respectfully submitted,
Louis H. Kenney, U.S., M.

TOOL PLANT.
TEST OF HIGH SPEED TOOL STEEL.

MACHINERY DIVISION, NAVY YARD, PHILADELPHIA, PA.
SCALE ..... = 1 FOOT
DATE 1911
DRAWN BY .....
TRACED BY .....
CHECKED BY .....
APPROVED BY .....
SUBMITTED BY .....
CHIEF CONSTRUCTOR U.S.N.
AND ENGINEER-IN-CHIEF
SHEET NUMBER 607

As per 47-3-5

As per Schedule 3244.

5-1/	6-2	6-3	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	4-3	5-1	5-3	5-2	5-4	6-2	6-3
21.65	22.05	23.00	12.62	14.10	15.25	12.23	13.71	12.60	16.56	17.62	16.32	14.62	15.91	12.50	28.20	28.26	4.97	6.48	3.82	5.07
16.65	15.97	12.75	3.85	15.78	14.86	4.25	7.82	10.07	10.16	12.00	9.80	13.02	12.68	11.04	---	---	---	---	---	---
15.90	21.32	7.82	3.72	14.17	14.30	15.04	11.04	2.62	11.91	22.95	1.11	23.40	6.22	14.66	---	---	---	---	---	---
18.35	14.60	8.62	12.45	14.71	13.20	13.31	6.52	9.44	14.65	8.19	6.24	17.00	12.77	12.30	---	---	---	---	---	---
	20.91			14.18			11.09			17.73			14.05		24.28		6.46		2.71	
45	45	45	44	45	46	45	45	45	45	46	45	45	45	45	35	35	55	55	65	65
45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	---	---	---	---	---	---
45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	---	---	---	---	---	---
44	45	46	44.6	45	45	45	45	45	45	46	45	45	45	45	---	---	---	---	---	---
	1/4			1/4			1/4			1/4			1/4		35		55		65	
1/4	1/2	1/4	1/4	1/2	1/4	1/4	1/4	1/4	1/4	1/2	1/4	1/4	1/2	1/4	1/4	1/4	1/4	1/4	1/4	1/4
1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
	1000			1450			1850			1150			1370		---		---		---	
	1000			682			540			867			728		---		---		---	
238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238	238
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7		13		16	
29-31	29-31	32-34	29-32	29-31	30-32	30-32	31-33	30-32	30-32	31-33	31-35	29-31	30-32	30-32	26-28	26-28	39-41	39-40	44-46	43-45
29-31	29-31	32-34	29-31	30-32	29-31	31-33	30-32	31-33	30-32	32-34	31-33	32-34	30-32	30-32	---	---	---	---	---	---
30-32	30-32	32-34	30-32	30-32	30-32	31-33	31-33	30-32	32-34	32-34	31-33	31-33	30-32	32-34	---	---	---	---	---	---
91	303	317	311	307	31	317	317	313	317	92	317	317	31	317	---	---	---	---	---	---
	31			310			316			318			315		27		395		445	
	7300			7355			7522			7568			7408		6426		7401		10581	
	2380			2380			2380			2380			2380		1666		3094		3900	
	5006			4976			5142			5188			5118		4760		4307		6783	
75	78	80	74	72	72	76	75	72	72	73	71	75	75	75	---	---	---	---	---	---
80	78	79	75	72	73	74	74	75	70	69	68	73	72	72	---	---	---	---	---	---
84	84	84	78	75	74	78	75	76	75	73	70	78	78	78	---	---	---	---	---	---
89	82	88	82	77	77	82	82	80	78	74	74	82	82	82	---	---	---	---	---	---
Treatment															Retreatment					
---	165	168	213	190	208	213	193	189	188	209	171	220	222	230	260	165	169	194	211	189
1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
2675	2675	2675	2575	2500	2560	2710	2710	2710	2718	2650	2710	2675	2675	2675	2675	2660	2660	2625	2615	2500
	45			42			42			45			44				-----			
	436			316			364			306			340				-----			
	1400			1440			1730			1450			1940				-----			
	1400			693			579			968			746				-----			
	1008			1020			1070			1000			1410				-----			
	1000			1080			933			1000			978				-----			
	45			312			243			390			328				-----			
	45			650			777			518			604				-----			

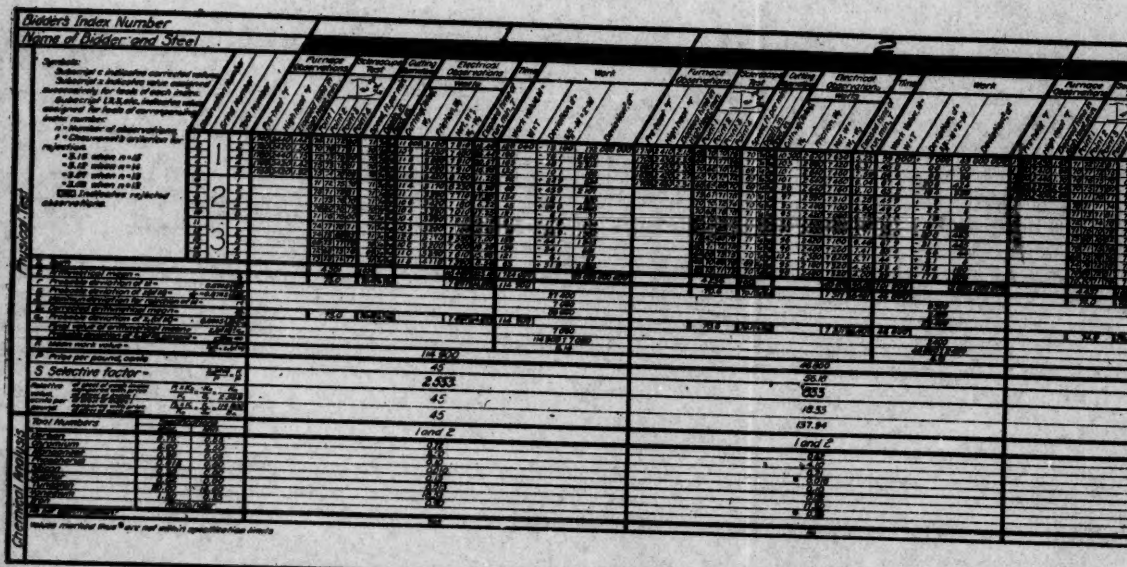
...country under ...tecture data ...were run with

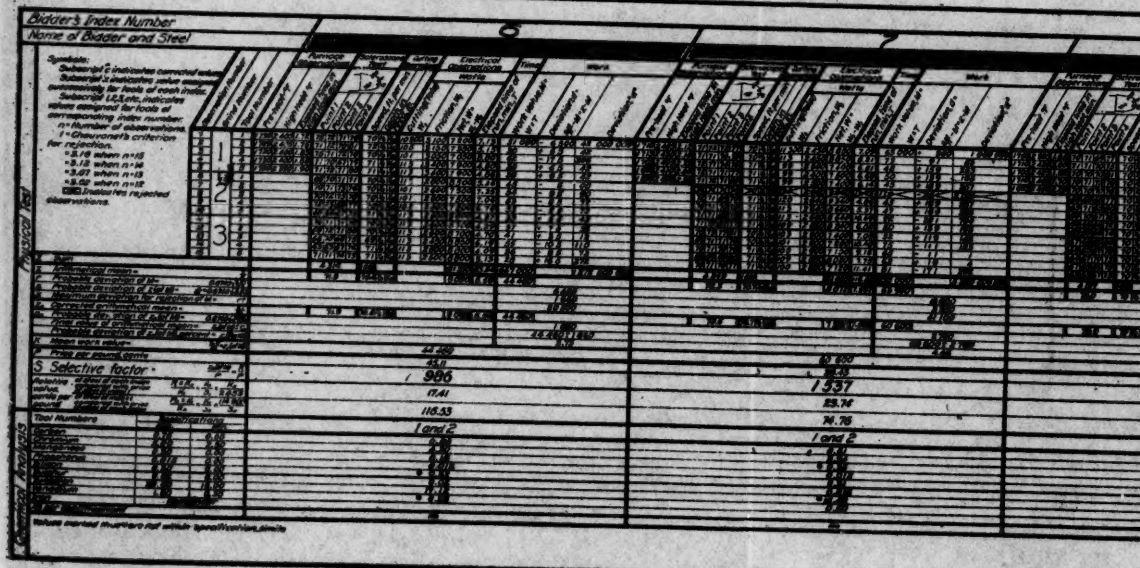
...tion	Vanadium
...Stock	.30 To .45
...968	.10 - .35

...6-3-(20-51)"
...Tools.
...Tools 6-2-(20-11)

...ld of other
...f other Tools
...ld of Tools 6-1
...Tools 6-1, 6-2 &3

...mary, M.S., M.F.


Bidder's Index Number
Name of Bidder and Steel
Physical Test
Chemical Analysis
Furnace Observations
Work
Electrical Observations
Time
Cutting
Tool Numbers
1
2
3
S Selective factor =
45
2.533
45
45
1 and 2


Bidder's Index Number
Name of Bidder and Steel
Physical Test
Chemical Analysis
Furnace Observations
Work
Electrical Observations
Time
Cutting
Tool Numbers
1
2
3
S Selective factor =
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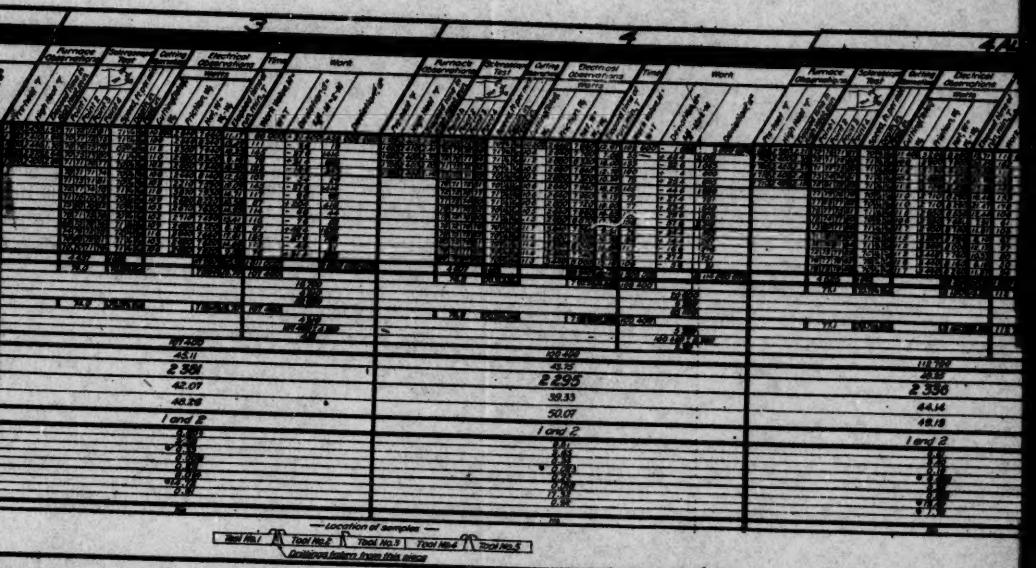
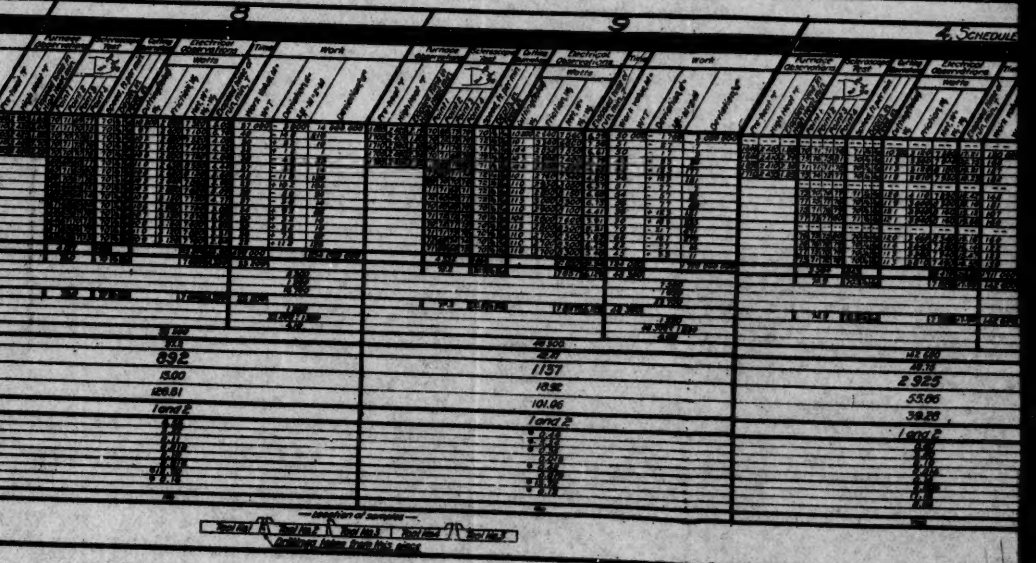
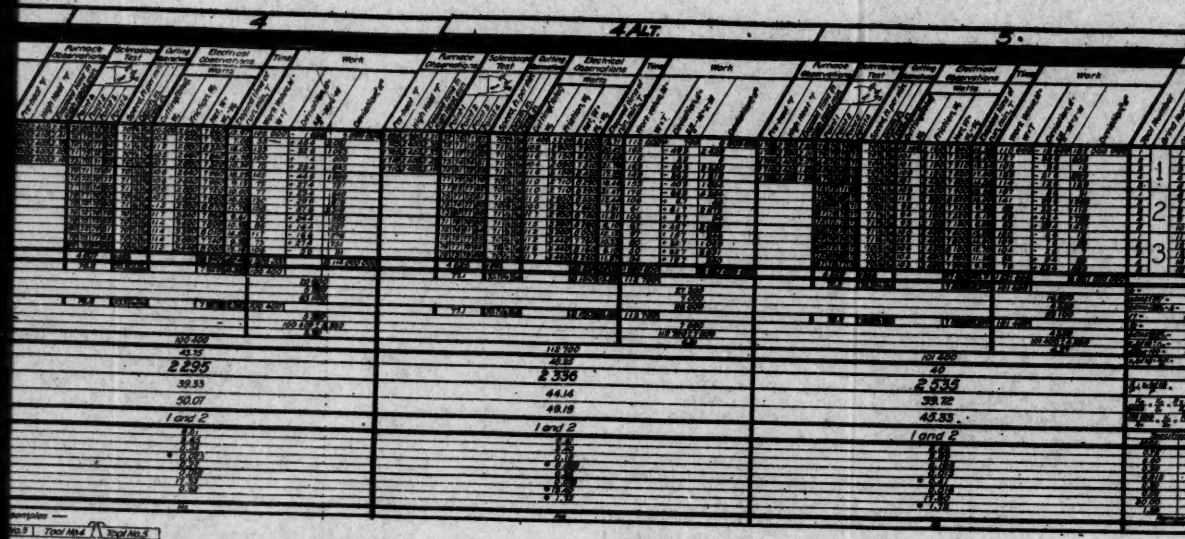
17.41
118.53
1 and 2


3
4
4A
Furnace Observations
Tool
Cutting
Electrical Observations
Time
Work
Tool No.1
Tool No.2
Tool No.3
Tool No.4
Tool No.5
— Location of samples —
Drillings taken from this piece


8
9
4.5 SCHEDULE
Furnace Observations
Tool
Cutting
Electrical Observations
Time
Work
Tool No.1
Tool No.2
Tool No.3
Tool No.4
Tool No.5
— Location of samples —
Drillings taken from this piece


4
4 ALT.
5.
Furnace Observations
Scleroscope Test
Cutting Observations
Electrical Observations
Watts
Time
Work
Remarks
2 295
39.33
50.07
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2 336
44.14
48.19
1 and 2
2 535
39.12
45.33
1 and 2
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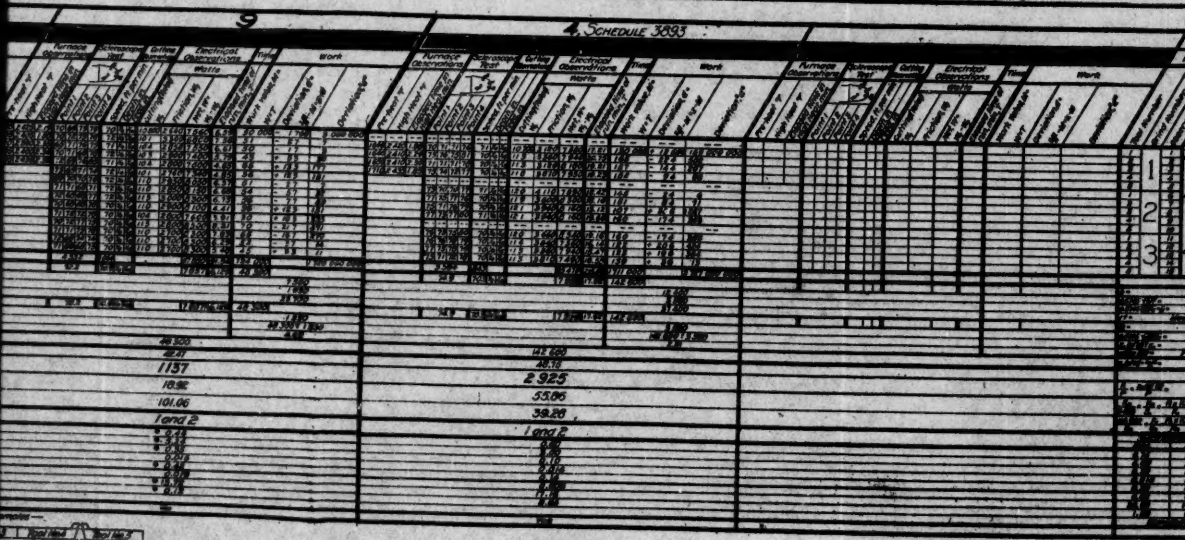
2
3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Furnace Observations
Scleroscope Test
Cutting Observations
Electrical Observations
Watts
Time
Work
Remarks
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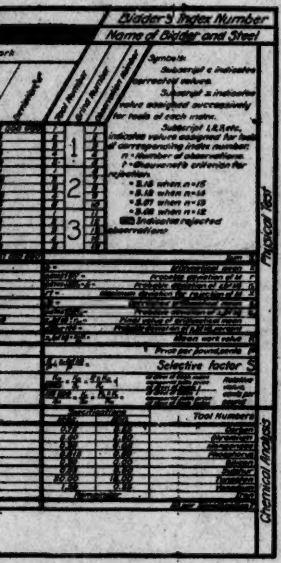
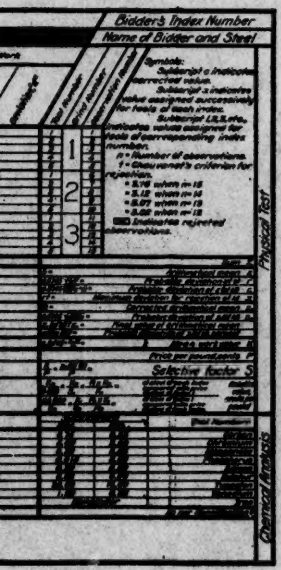
1 and 2
2 925
55.06
39.26
1 and 2
1
2
3





Material on Which Tools Were Tested.	Rod: Nickel Chrome Forging. Chemical Composition: C 0.30 / Mn 0.60 / Ni 1.00 / Cr 0.60 / W --- / Mo --- / V ---
Description of Tool.	Sellers's lathe tool form #30.
Lubricant.	None.
Condition of Tool at End of Run.	Ruined.
Adjustment of Observations.	Method of Least Squares, according to Merriman, for work value, $M_w = \frac{1}{K}$.
Basis of Absolute Comparison.	K = mean actual work done by tool. Ft-lbs. of work done by tool = $\frac{M_w}{K}$ lbs. cos = $\frac{M_w}{K}$ H.K. Then foot-pounds of work done by tool = K.
Price, cents per pound.	P = price quoted per pound where a uniform price per pound is quoted by a bidder. P = total price quoted divided by total weight, where two or more prices per pound are quoted by a bidder.
Selective Factor.	Ratio of Basis of Absolute Comparison to price per pound.
Relative Value.	1. Value, in cents per pound, of material of each index compared with quoted price of material of index having highest selective factor. 2. Value of material of index having highest selective factor compared with quoted price of material of each index.

Notes:-

Specifications distinctly state that failure of a bidder to comply with all the requirements of the specifications would eliminate such bid from consideration. Accordingly, this report includes only those tool steels, proposals for which were not eliminated as noted above.

The report gives the chemical analyses of the samples together with the data and description of the test, also the method of determining the selective factor. The highest selective factor determined the recommendation for award of contract.

In order to compare the tool steel of highest selective factor in the selective test under schedule 3295 with these sample steels, the identical tools used in that test, with the exception of "I" which was missing, were treated and tested under the same conditions prevailing during this selective test.

It will be noted that the chemical composition of the tool steel of highest selective factor is within the specification limits.

Respectfully submitted,

Laurence V. Cromwell B.S., M.E.

Member American Society of Mechanical Engineers
Member American Society for Testing Materials

SELECTIVE TEST.
TUNGSTEN TOOL STEEL, CLASS I.
SCHEDULE 4469.

MACHINERY DIVISION.

SHEET NUMBER 1520

Bidder's Index Number	1	2
Name of Bidder and Steel.		
Observations 1–15 (Grinds 1, 2, 3; Tool Numbers 1–5): Furnace Observations, Scleroscope Test, Electrical Observations, Cutting Speed, Time Observations	[illegible]	[illegible]
Σ Sum	4274 … 3522 … 5.068	4460 … 7480
z Arithmetical mean =	71.2 …	74.3 …
r Probable error of individual observation	0.406	1.071
r_0 Probable error of z =	0.105	0.276
Limiting error for rejection =	1.283	3.381
z_c Corrected arithmetical mean =	71.2 …	74.1 … 4.701
Probable error of z_{c}	.0165	.0219
Final value of arithmetical mean =	[illegible] ±.0165	4.701 ±.0219
Probable percentage error =	.445	.466
W_c Watts Total (cutting) =	9490	9803
W_f Friction =	3963	3905
W Net =	5527	5898
K Work value (Price not considered) =	12 977	27 725
P Price per pound, cents	39	44
S Selective factor =	332.7	630.1
Relative value	15.10	32.26
cents per pound	125.92	66.49

Symbols:–
Subscript c indicates corrected values.
Subscript ʺ indicates value assigned successively for tools of each index.
Subscript 1,2,3, etc. indicates values assigned for tools of corresponding index number.
n = Number of observations.
T = Chauvenet's criterion for rejection.
= 2.13 when n = 15
= 2.10 when n = 14
[illegible] indicates rejected observations.

Tungsten Tool Steel Class I.

Chemical Analysis.																	
Index	Specifications Max.	Min.	1		2		3		4		5		6		7		8	
Tool Numbers			1 and 2	4 and 5	1 and 2	4 and 5	1 and 2	4 and 5	1 and 2	4 and 5	1 and 2	4 and 5	1 and 2	4 and 5	1 and 2	4 and 5	1 and 2	4 and 5
Carbon	.55 to	.65	• .545	.556	.615	.600	.605	.600	.600	.595	• .540	• .545	• .545	.550	.710	.720	• .410	• .420
Chromium	5.00 to	2.50	2.770	2.830	3.960	3.910	3.330	3.450	3.000	2.970	• 5.550	• 5.580	4.450	4.440	4.850	4.920	3.350	3.300
Manganese	.30 to	.15	.190	.200	.190	.200	.100	.100	.100	.100	.170	.170	.250	.250	.300	.250	[illegible]	[illegible]
Phosphorus	.015 to	.00	.015	.014	.011	.010	.015	.015	.014	.014	.015	.015	.009	.009	.014	.014	• .023	• .022
Silicon	.30 to	.00	.160	.160	.180	.160	.160	.180	.140	.140	.130	.140	• .310	.300	• .310	• .310	.100	.110
Sulphur	.02 to	.00	.010	.008	.007	.008	.006	.006	.006	.006	.007	.009	.013	.012	.016	.017	.016	.016
Tungsten	20.00 to	16.00	17.280	17.250	• 15.500	• 15.560	• 15.400	• 15.500	17.160	17.030	18.000	18.700	18.000	18.040	19.030	19.770	• 12.120	• 12.000
Vanadium	— — to	.35	• .050	• .050	.620	.630	.400	.450	.240	.240	• .400	• .400	• .120	• .120	.510	.510	• .000	• .000
Iron	Remainder																	
As per Specification?			No		No		No		Yes		No		No		No		No	

Values marked thus • are not within specification limits.

—Location of samples—

Tool No. 1 | Tool No. 2 | Tool No. 3 | Tool No. 4 | Tool No. 5

Drillings taken from these places.

Carbon Tool Steel Cl[ass]

Bidders Index Number	Specifications Maximum	Minimum	1	3	4
Chemical Analysis. Carbon	1.20 to	1.15	[illegible]	[illegible]	[illegible]
Chromium	Optional				
Manganese	[illegible]		[illegible]	[illegible]	[illegible]
Phosphorus	[illegible]		[illegible]	[illegible]	[illegible]
Silicon	[illegible]		[illegible]	[illegible]	[illegible]
Sulphur	[illegible]		[illegible]	[illegible]	[illegible]
Vanadium	Optional				
Iron	Remainder				
As per specification?			Yes	Yes	Yes
Physical Test. Furnace temperature quenched in brine	1450° F.	Tool No.	Elapsed time		
Temper drawn in lead bath to	450° F.	1	[illegible]	[illegible]	[illegible]
Revolutions per minute of cutter	[illegible]	2	[illegible]	[illegible]	[illegible]
Depth of cut, inches	[illegible]	3	[illegible]	[illegible]	[illegible]
Feed, inches per minute	[illegible]	4	[illegible]	[illegible]	[illegible]
z Arithmetical mean			[illegible]	[illegible]	[illegible]
P Price per pound, cents			[illegible]	[illegible]	[illegible]
S Selective factor			[illegible]	[illegible]	[illegible]
Relative Value			4.26	4.35	12.[illegible]
cents per pound			28.20	27.50	[illegible]

Kind of Tool Steel.	Material on Which Tools Were Tested: Kind	Physical: T.S.	E.L.	Chemical: C	Cr	Mn	Ni	P	Si	S	Description of Tool.	Lubricant	Condition of Tool at End of Run.
Tungsten Class 1	Nickel steel forging	102500	63500	.370	---	.700	3.60	.021	.182	.022	Sellers's lathe tool form No. 30.	None	Ruined
Carbon Class 1	⅝" Ship plate	58410	22060	[illegible]	---	.370	---	[illegible]	[illegible]	[illegible]	An adaptation of milling cutter as given by Mr. A. L. DeLeeuw in Transactions of Amer. Soc. of M.E.	None	Broken in shank or tee[th]
Carbon Class 2	⅝" Ship plate.	58410	22060	[illegible]	---	[illegible]	---	[illegible]	[illegible]	[illegible]	(same as above)	None	Broken in shank or teet[h]
Carbon Class 3	Nickel steel plate annealed	81750	59060	.230	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Cape chisel.	Oil	Broken or cutting edge fai[led]
Carbon Class 4	½" Hot rivets.	---	---	---	---	---	---	---	---	---	½" Rivet set	None	Not ruined.

Tungsten Tool Steel Class 1.

3 | 4 | 5

Furnace Observations | Scleroscope Test | Electrical Observations | Cutting Time Observations

Steel Class 1.

Carbon Tool Steel Class 2

Bidder's Index Number | Specifications | 1 | 3 | 4 | 5 | 7

Chemical Analysis: Carbon (Total C, Graphitic C, Combined C); Manganese; Phosphorus; Silicon; Sulphur; Vanadium; Iron; As per specification?

Physical Test: Furnace Temperature (Heated in bath, Temper drawn in lead bath); Revolutions per minute of carborundum wheel; Depth of cut, inches; Feed, inches per revolution; Antimonial lead; Is Point Pen Ground, Conical; S Selective factor; Relative efficiency of each cutting edge; Value; cents per pound

Elapsed time of run, minutes.

Carbon Tool Ste

Bidder's Index Number | Specifications | 1

Chemical Analysis: Carbon (Total C, Graphitic C, Combined C); Manganese; Phosphorus; Silicon; Sulphur; Vanadium; Iron; As per specification?

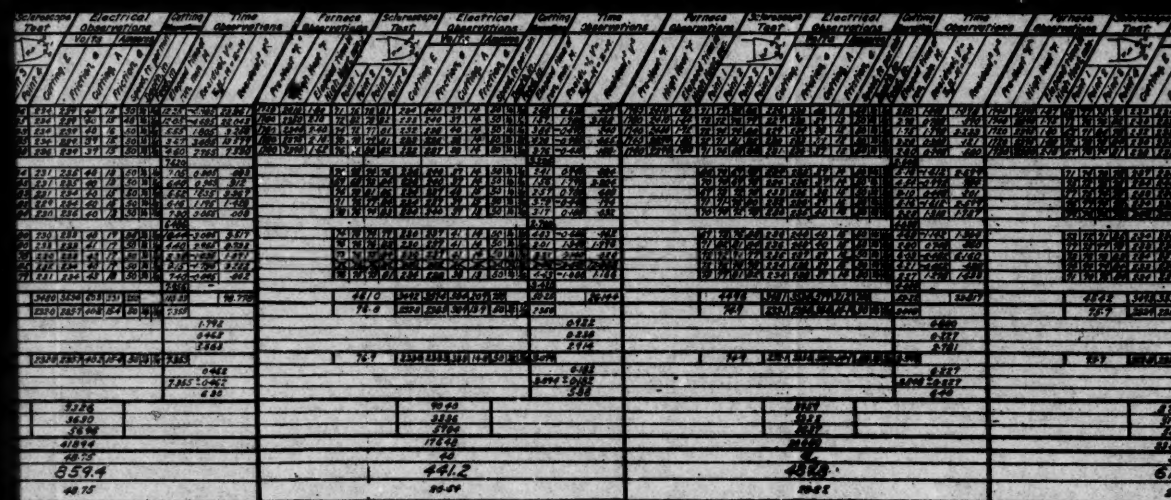
Physical Test: Furnace Temperature (Heated in bath, Temper drawn in lead bath); Revolutions per minute of carborundum wheel; Depth of cut, inches; Feed, inches per revolution; Antimonial lead; Is Point Pen Ground, Conical; S Selective factor; Relative efficiency of each cutting edge; Value; cents per pound

Explanation of Test.

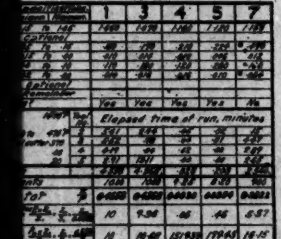
Condition of Tool at End of Run.	Adjustment of Observations	Basis of Absolute Comparison	Price, cents per pound	
Ruined	Method of Least Squares, according to Nerriman, for elapsed time of run, ft. basis.	T = Mean actual work done by tool. Note: of work done by tool = ... This Increments of work done by tool in ft.	P = price quoted per pound, where a uniform price per pound for material of one class is quoted by a bidder. P = total price quoted for material of one class divided by total weight of material of that class, where two or more prices per pound for material of one class are quoted by a bidder.	Ratio of
...en in shank or teeth.	None	T = Mean elapsed time of run.		...atio of
...en in shank or teeth.	None	T = Mean elapsed time of run.		Ratio of
...n or cutting edge failed.	Two poorest rejected	T = Mean distance tool cut.		Ratio of
Not ruined.	None	Condition of tool at end of run.		Remarks

Tungsten Tool Steel Class 1.

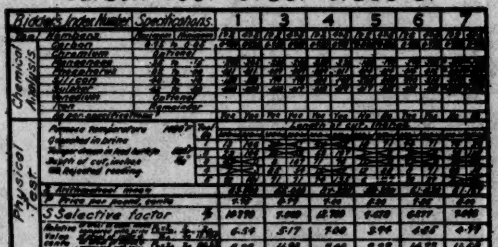
4 5 6



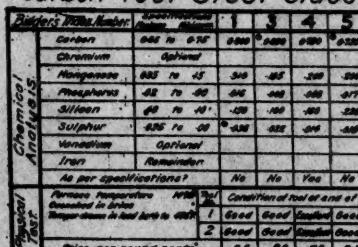
ol Steel Class 2



Carbon Tool Steel Class 3.

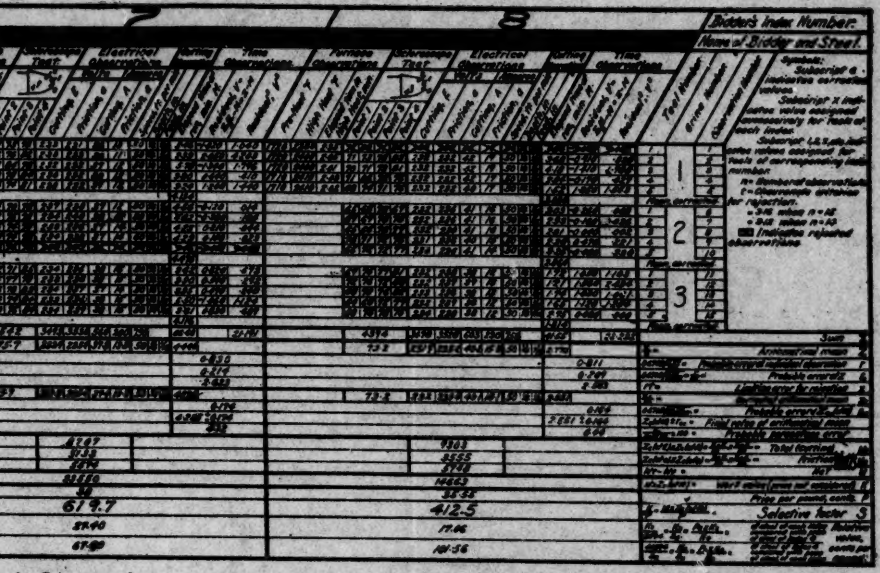


Carbon Tool Steel Class



t.

Basis of Absolute Comparison.	Price, cents per pound.	Selective Factor	Relative Value.	Kind of Tool
Mean actual work done by tool.	P = price quoted per pound, where a uniform price per pound for material of one class is quoted by a bidder.	Ratio of Basis of Absolute Comparison to price per pound	1. Value, in cents per pound, of material of each index compared with quoted price of material of index having highest selective factor.	Tungsten Cl
Mean elapsed time of run.	P = total price quoted for material of one class divided by total weight of material of that class, where two or more prices per pound for material of one class are quoted by a bidder.	Ratio of Basis of Absolute Comparison to price per pound	2. Value of material of index having highest selective factor compared with quoted price of material of each index.	Carbon Class
Mean elapsed time of run.		Ratio of Basis of Absolute Comparison to price per pound		Carbon Cla
Mean distance tool cut.		Ratio of Basis of Absolute Comparison to price per pound		Carbon Cla
ndition of tool at end of run.		Condition of tool at end of run.		Carbon Cla



Class 4.

3	4	5	7
.0490	.0330	.0330	.0190
.035	.030	.028	.040
.040	.040	.017	.010
.100	.100	.030	.130
.022	.010	.010	.044
No	Yes	No	No
tion of tool at end of test			
Good	Excellent	Good	Good
Good	Excellent	Good	Good
8.8	7.8	3.2	7.9

Identification Table.

Index	Name of bidder	Trade name of tool steels. Tungsten Class 1	Carbon Class 1	Carbon Class 2	Carbon Class 3	Carbon Class 4
1						
2						
3						
4						
5						
6						
7						
8						

* Indicates tool steels having highest selective factor

Kind of Tool Steel
Tungsten Class 1
Carbon Class 1
Carbon Class 2
Carbon Class 3
Carbon Class 4

Notes-

Specifications distinctly state that failure of a bidder to forward samples to General Storekeeper at Navy Yard, Philadelphia, Pa., at or before the time set for opening bids would eliminate such bid from consideration. Accordingly, this report includes only those tool steels, proposals for which are not eliminated as noted above.

The report gives the chemical analyses of the samples together with the data and description of the tests also the method of determining the selective factor. The highest selective factor determined the recommendation of award of contracts.

The tool steels having the highest selective factor are indicated thus * in the identification table.

It will be noted that the chemical composition of these tool steels having the highest selective factor is within the specification limits in each case.

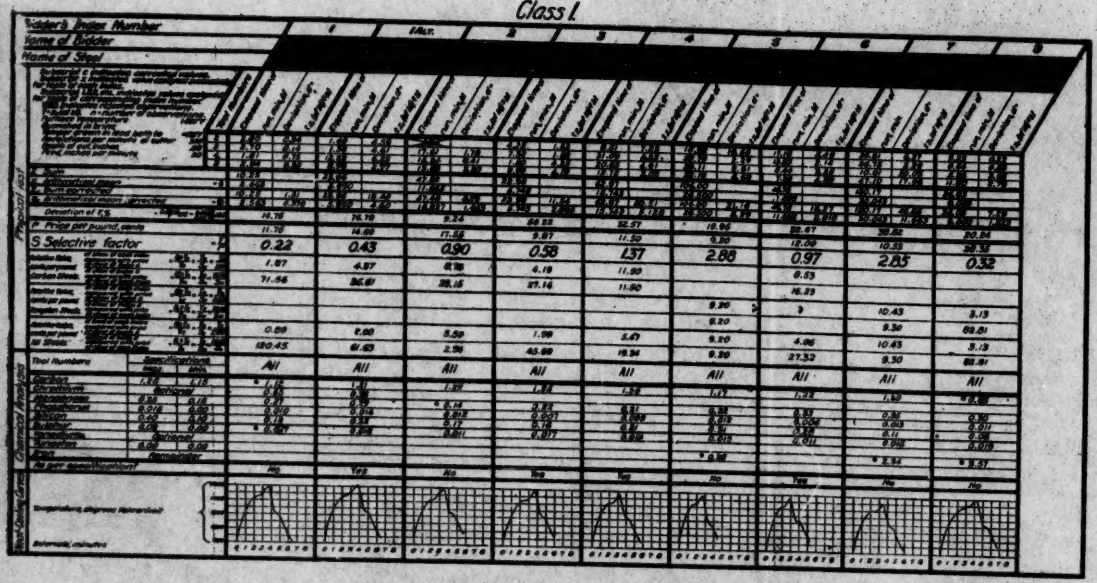
Respectfully submitted,

Louis A. Fanning, U.S.N.R.

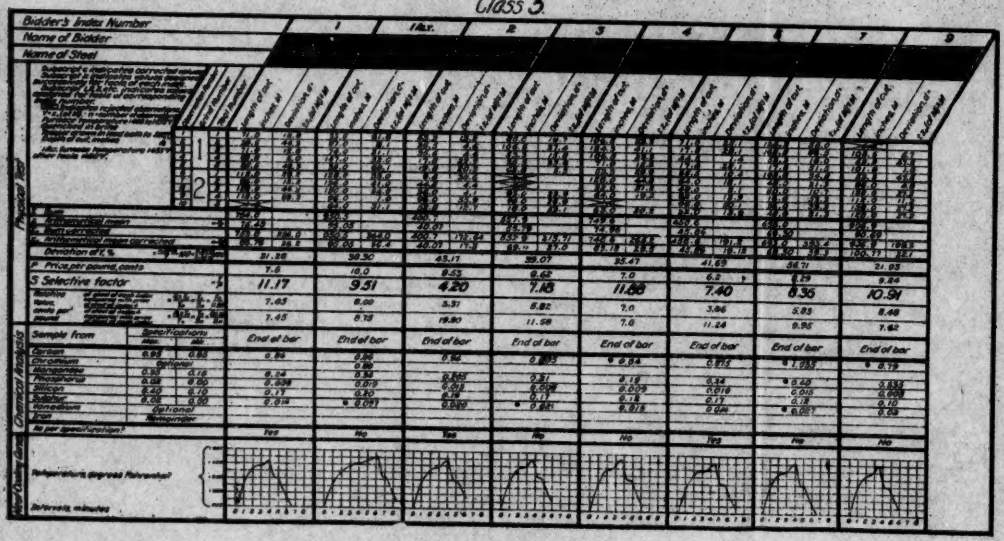
EASTERN NAVY YARDS.
TEST OF TOOL STEELS
UNDER SCHEDULE 3853

1058

Class 1.



Class 3.



Class 2.

Bidder's Index Number	1	1Bis.	2	3	4	5
Name of Bidder						
Name of Steel						
Physical Test						
Chemical Analysis						
Heat Cooling Curves						
Price per pound, cents	11.38	16.89	14.13	9.98	8.00	9.19	9.85
S Selective factor	1.08	1.42	0.62	0.72	0.67	0.79	2.98
cents per pound	8.67	13.59	8.43	5.07	4.25	5.09	9.85
	13.76	19.59	38.94	26.64	23.63	26.39	9.85
	4.08	6.44	3.06	2.41	1.82	2.43	9.85
	34.38	50.05	46.38	36.54	42.49	36.04	9.85
Tool Numbers	All	All	All	All	All	All	All
Carbon	1.19	1.19	* 1.32	1.08	* 0.98	1.08	* 0.98
Chromium		1.19					
Manganese	0.34	0.34					
Phosphorus	0.013	0.013	* 0.14	0.32			
Silicon	0.20	0.20	0.207	0.008	0.185	0.24	* 0.30
Sulphur	0.02	0.02	0.017	0.008	0.009	0.018	0.012
Vanadium	0.01	0.20	0.013	0.18	0.19	0.21	0.18
Tungsten	0.02	0.02		0.012		0.018	
Iron							* 3.38
As per specification?	Yes	Yes	No	Yes	No	Yes	No

Class 4.

Bidder's Index Number	1	3	4	5	7	9
Name of Bidder						
Name of Steel						
Physical Test						
Chemical Analysis						
Heat Cooling Curves						
Furnace temperature when inserted (to be the same when each bar is put in)	Test No.	Condition of tool at end of test					
	1	Good	Good	Good	Good	Good	Good
	2	Good	Good	Good	Good	Good	Good
Price per pound, cents		8.35	7.48	7.00	6.30	7.71	7.90
Tool Numbers		All	All	All	All	All	All
Carbon	0.85 / 0.75	0.79	* 0.90	0.85	0.825	* 0.93	* 0.98
Chromium	Optional						
Manganese	0.35 / 0.15	0.36	0.325	0.25	0.24	* 0.39	0.29
Phosphorus	0.02 / 0.00	* 0.022	0.042	0.013	* 0.079	0.016	0.018
Silicon	0.40 / 0.10	0.13	0.15	0.12	0.15	0.12	0.15
Sulphur	0.025 / 0.00	10.014	0.021	0.018	0.019	* 0.027	0.019
Vanadium	Optional						
Iron	Remainder						
As per specification?		No	No	Yes	No	No	No

Tungsten Tool S

Spec. 47 S

Bidder's Index Number	
Name of Bidder	
Name of Steel	
Physical Test	
Chemical Analysis	
Heat Cooling Curves	
Carbon	1.60
Chromium	Optio
Manganese	0.30
Phosphorus	0.015
Silicon	0.30
Sulphur	0.03
Tungsten	3.00
Vanadium	Optio
Iron	Remai
As per specification?	

Class 2.

	1	1 Max.	2	3	4	5	7	9
Bar Numbers								
Chemical Analysis								
Physical Test								
Tool Numbers								
Physical Test								
Chemical Analysis								
Heat-Cooling Curves								

Class 4.

3	4	5	7	9
Condition of tool at end of test				
Good	Good	Good	Good	Good
Good	Good	Good	Good	Good
7.46	7.00	6.80	7.11	7.00
All	All	All	All	All
*0.90	0.85	0.825	*0.93	*0.98
0.825	0.82	0.24	*0.39	0.29
0.012	0.012	*0.013	0.014	0.018
0.18	0.12	0.15	0.12	0.15
0.021	0.018	0.015	*0.027	0.019
No	Yes	NO	No	NO

Tungsten Tool Steel, Class 2.

Spec. 47 S 5 July 30, 1914

Bidder's Index Number					
Name of Bidder					
Name of Steel					
Physical Test — Tool Numbers					
Subscript c indicates corrected values. Furnace temperature 1485°F					
Quenched in brine					
Temper drawn in lead bath to	430°				
Readings per minute of cutter	2				
Depth of cut inches	.05				
Feed, inches per minute	.25				
				3	26.65 0.14
				4	12.92 15.67
				5	27.74 0.35
				6	25.76 4.73
Σ. Sum					113.35
$\bar{x}$. Arithmetical mean				$\bar{x}$	28.488
Σ. Sum corrected					113.35 34.79
$\bar{x}_c$ Arithmetical mean corrected				$\bar{x}_c$	28.488 8.698
Deviation of $\bar{x}_c$ of (4), percent				$\bar{x}_c$	30.53
Chemical Analysis		Specifications Max.	Specifications Min.		
Carbon		1.50	1.35		1.37
Chromium		Optional			
Manganese		0.20	0.10		*0.235
Phosphorus		0.015	0.00		0.01
Silicon		0.30	0.00		4 *0.45
Sulphur		0.03	0.00		0.009
Tungsten		5.00	2.00		3.87
Vanadium		Optional			
Iron		Remainder			
As per specification?					No
Heat-Cooling Curves — Temperature, degrees Fahrenheit					
Intervals, minutes					

Class Number		
Materials on Which Tools Were Tested	Kind	
	Physical Properties	T.S.
		E.L.
		E
	Chemical Composition	Mn.
		Ni.
		P
		Cr.
		S
Description of Tool		
Lubricant		
Condition of Tool at End of Run		
Adjustment of Observations		
Basis of Absolute Comparison		
Price per pound, cents		
Selective Factor		
Relative Value		
Heat-Cooling Curves		

Notes:—

Specifications distinctly state that ... with all the requirements of the specifications ... but from consideration. Accordingly, this ... tool steels, proposals for which were elimin...

The report gives the chemical analysis ... with the date and description of the test, ... ing the selective factor. The recommended ... was determined by the highest selective ... and by the price per pound, due consider... condition of the tools at end of test, for Cla...

Some of the samples submitted und... tungsten although that element was not in... Three relative values, therefore, were comp... containing tungsten, for samples contain... 2 samples. A sample of Tungsten Tool Steel ... specifications 613.3 of July 30, 1914 was tes... ditions prevailing during this selective te... above mentioned steels containing tungst... the time of run of tools containing tungste... content conformed to class requirements, ... that of tools not containing tungsten.

Explanation of Tests:

		1	2	3	4
		Ship Plate	Ship Plate	Nickel Steel Plate, annealed	Rivet Rivets
	T.S.	60 000 pounds per square inch	60 000 pounds per square inch	89 700 pounds per square inch	— —
	E.L.	30 000 pounds per square inch	30 000 pounds per square inch	59 760 pounds per square inch	— —
	C	0.450	0.450	0.620	— —
	Mn	0.460	0.460	0.560	— —
	Ni	0.000	0.000	3.960	— —
	P	0.048	0.008	0.010	— —
	Si	0.080	0.050	0.010	— —
	S	0.046	0.044	0.016	— —
		An adaptation of milling cutter as given by Mr. A. L. De Leeuw in Transactions of Amer. Soc. of M.E.		Cape Chisel	Rivet Set
		None	None	Oil	None
End of Run		Broken in shank or teeth	Broken in shank or teeth	Broken or cutting edge failed	Not ruined
ervations		Observation which indicated the tool was not representative was rejected	None	Observation which indicated the tool was not representative was rejected	None
Comparison		Y=mean elapsed time of run	Y=mean elapsed time of run	Y=mean distance tool cut	None
nts		P= price quoted per pound where a uniform price per pound is quoted by a bidder P=total price quoted divided by total weight, where two or more prices per pound are quoted by a bidder			
		Ratio of Basis of Absolute Comparison to price per pound			None
		I. Value, in cents per pound, of material of each index compared with quoted price of material of index having highest selective factor 2. Value of material of index having highest selective factor compared with quoted price of material of each index			None corrected
ces		Determined by Recalescent Apparatus			

...ghtly state that failure of a bidder to comply ...te of the specifications would eliminate such ...n. Accordingly, this report includes only those ...for which were eliminated as noted above. ...the chemical analyses of the samples together ...ion of the test, also the method of determin... ...or. The recommendation for award of contract ...e highest selective factor for Classes 1,2 and 3 ...pound, due consideration being given to the ...al end of test, for Class 4. ...mples submitted under Classes 1 and 2 contained ...ar element was not included in the specifications, ...therefore, were computed; for samples not ..., for samples containing tungsten and for all ...f Tungsten Tool Steel, Class 2, purchased under ...of July 20, 1911 was tested under the same con... ...ning this selective test for comparison with the ...mples containing tungsten. It will be noted that ...ls containing tungsten, provided the carbon ...class requirements, was much longer than ...aining tungsten.

Respectfully submitted,

Lewis M. Umbsted, Sp., M.E.

Member American Society of Mechanical Engineers
Member American Society for Testing Materials

SELECTIVE TEST.
CARBON TOOL STEELS, CLASSES 1, 2, 3 and 4.
SCHEDULE 4469.

MACHINERY DIVISION,
Date Work, Philadelphia, Pa.
Name . . . .
Date . . . January 23, 1912.
Drawn By . . . A.S.C. & L.M.U.
Weight of . . . .
Checked By . . . .
Approved . . . .
Date Traced to Record Sheet . . . .

GHEST NUMBER 1521

THE PROGRESS OF WARSHIP ENGINEERING.

The relative merits of the steam engine and the internal-combustion engine for ship propulsion have occupied the attention of engineers for some years past, and the development of the internal-combustion engine for the propulsion of commercial ships has led some people to think that the subject was not receiving the attention it should from naval authorities, seeing the small extent to which such systems have been employed in naval ships up to the present. Many advantages have been claimed and proved on the side of the internal-combustion engine particularly. For warship propulsion, for example, such an engine is entirely self-contained and independent, it does not receive its motive power from a distance, the absence of boilers and large funnels allows a more efficient arrangement of guns and magazines, and diminishes to a considerable extent the possible amount of wreckage during an action. The troubles that have been in evidence recently in steam-driven craft owing to the too close proximity of the bridge and forward funnel to one another are avoided, while the fact of no smoke and no flame being produced increases the invisibility of the vessel, not only by night but also by day. The importance of this point will be readily recognized by anyone who has seen recent photographs of warships running at full speed. The "ever readiness" of the motor warship is a feature of advantage of the greatest importance. There is no lighting of fires required or any necessity for waiting to get up steam, no banking of fires in the case of a long and anxious blockade so as to maintain such conditions as to be ready to start off in pursuit of an enemy at a moment's notice; in fact, the measure of a vessel's readiness may be taken as the time necessary for buoying and slipping her cable. Quick coaling, even at a great expenditure of energy on the part of a ship's company, has also been considered a matter of the greatest importance, but the irritating and wearisome character of the work carried out after coming back from an action, having to go out again and fight immediately, when coaling is completed, is entirely obviated when using oil fuel, as the operation can be effected without calling upon the crew for any energy whatever, and, it must be remembered, can be carried out at sea in weather which would preclude the possibility of the transfer of coal at all. We need not go into another feature which has been dealt with so fully over and over again, viz.: the radius of action of a motor warship being nearly three times that of a steamship with coal-burning boilers of an equivalent displacement, or nearly twice as much as a steamship using liquid fuel in her boilers. It is now generally recognized that the strategic advantages of the motor ship over the steamship are very great. We should now like to draw attention to an aspect of the question which, as far as we know, is an entirely novel one, and is presented by Mr. C. De Grave Sells in the 1912 edition of "Fighting Ships," which appears to us to be of such importance as to deserve the fullest publicity. Mr. Sells, while recognizing all the advantages, points out certain counter-balancing disadvantages, which we feel sure must be realized only too well by those who have had experience with the new class of machinery. In fact, to put it shortly, the drawbacks which manifested themselves in the steam reciprocating-engine of the past are developing themselves even in a more pronounced form in the quick-running oil engines of large power of today, and there is no wonder that the naval engineer and naval architect are somewhat loth to encourage development along the suggested line, having regard to their steam experience in front of them. It can be said that there is no want of enterprise, as such has been proved over and over again by the way in which the turbine steam engine has been adopted by so many engineers and ship-owners as soon as its advantages had been thoroughly established. It will be remembered that before the steam turbine had been brought to a condition of practical success, the running of full-power trials with reciprocating engines was only done by the imposition of

immense strain both on the men and on the machinery. The efforts made to obtain lightness in the propelling machinery and to cut down the weight and sizes of boilers only increased the difficulty of maintaining the steam pressure, and the greater part of the battle of a full-power trial had to be fought out in the boiler rooms. When the boiler side of the problem had been tackled, it only meant that the battle was transferred to the engine room. The number of revolutions was increased, while the stroke had to be kept comparatively short in order to keep the cylinders below the protective deck, which in its turn was kept below the water line. The inevitable difficulties which always manifest themselves in every mechanical device for transforming a reciprocating motion into a circular one were continually being increased, and it was a matter of sincere congratulation to all parties when a long trial run at full power was completed without difficulty or without mishap, and then only owing to the intense vigilance on the part of those responsible. It was after a period of such conditions that an entire change came about with the advent of the turbine engine, and neglecting for the moment the small troubles that are always experienced with new machinery and have to be overcome, the onerous conditions which obtained with a reciprocating engine entirely vanished when the steam turbine took its place. Not only did all the troubles as regards running and upkeep incidental to a reciprocating engine disappear, but it was found that there was no greater difficulty at full-speed running than at low-speed running, and the engine-room staff were not taxed to any greater extent in one case than in the other. In view of the fact that this change from the reciprocating engine to the purely rotary engine is so recent, it is not surprising that there is a distinct disinclination to hastily return to a reciprocating engine until such engine shall have been thoroughly well tested under all possible conditions, and one is satisfied that inevitable difficulties incidental to a new motor are overcome in an assured manner before the abandonment of a type of engine which has proved to have such immense advantages over what was in use before it. One is forced to the conclusion that for many of the services that are required of a warship steam will probably prove the best motive power for some time to come, and further, for both the main propelling engines and the auxiliary machinery of large warships, there are many questions to be resolved and many difficulties to be overcome before internal-combustion engines of the reciprocating type become generally adopted for all purposes on such vessels. The various naval authorities are not leaving the matter to go by default, which is proved by what has been done in the British, German, Russian and United States navies, and we believe it is recognized that the rate of progress today is many times greater than that of any period during the past century, and that the progress of the last twelve months is greater than that of any preceding year. The rate of development in the year to come will be greater still, and one may predict that not only will a further advance of considerable magnitude be effected, but that such advance will have attached to it the greatest possible interest to, and bearing on, naval matters in the future.—"Marine Engineer and Naval Architect."

AN IMPERVIOUS CEMENT.

By Rear Admiral G. W. Baird, U. S. N., Member.

About two years ago, Prof. L. W. Page, of the Department of Agriculture, discovered that ordinary cement mixed, while wet, with about 10 per cent. of oil became non-absorbent of moisture.

Tests were made with great success, by floating little cement boats in tanks of water, by filling and sealing jars, and by exerting water pressure upon discs of this material.

The strength of the oil-mixed cement is, when new, not quite so great as ordinary cement without the oil, but it becomes stronger with age and shows a constant increase in strength. This material may be used, I think, to advantage in any place subjected to moisture in the same way as ordinary cement and is quite as easily handled. Its use in cementing ships' bilges, waterways, etc., would be very desirable. Its index of expansion is practically the same as that of rolled iron (or steel), and it will, therefore, not crack from change of temperature when used in combination with ships' plates or in reinforced concrete, and has already been extensively used in experimental paving, in bridge work and in roofing.

For a waterproof mixture Prof. Page uses a concrete in the proportion of one part of cement to six parts of the aggregate; the sand and stone or gravel composing the aggregate should be combined in such proportions as to produce maximum density. The amount of oil used in this mixture is 10 per cent. of the weight of the dry cement.

The oil used, is a residual oil from which all the lighter hydrocarbons have been distilled. It should have a flash point above 350 degrees F.

The cement and sand are mixed dry until of uniform color, water is added gradually until a mortar is produced of a mush consistency. The oil is then added gradually, and the whole worked thoroughly and rapidly until a homogeneous mixture is obtained.

For cementing bilges, waterways, etc., the mixture should be one part of strong Portland cement to two parts of sand, with the same weight of oil as above recommended (10 per cent. of the dry cement).

SHIPS.

UNITED STATES.

Bids for the construction of destroyers Nos. 51–56 were opened on November 18, 1912. The name of each vessel, the type of machinery to be installed and the firm to which the contract was awarded are given below as follows:

O'Brien, Nicholson, Winslow.—2-shaft, with Cramp turbines and reciprocating engines. Contract awarded to The William Cramp and Sons Ship and Engine Building Company, Philadelphia, Pa.

McDougal.—Parsons turbines and reciprocating engines. Contract awarded to the Bath Iron Works, Bath, Maine.

Ericsson.—Parsons turbines and reciprocating engines. Contract awarded to the New York Shipbuilding Co., Camden, N. J.

Cushing.—Curtis turbines and reciprocating engines. Contract awarded to the Fore River Shipbuilding Co., Quincy, Mass.

Submarines.—Award of contract for the construction of eight submarine boats has been made as follows:

L-1, L-2, L-3, L-4 and *M-1*, to the Electric Boat Company.

L-5, L-6 and *L-7*, to the Lake Torpedo-Boat Company.

Bids for Battleship No. 38, the *Pennsylvania*, were opened on February 18, 1913. Contract was awarded to the Newport News Shipbuilding and Dry Dock Company. The machinery will be 4-shaft Curtis turbines with reduction gear on the low-pressure shafts.

FOREIGN SHIPBUILDING PROGRAM.

The following compilation made by the office of naval intelligence containing data regarding the building programs of foreign navies was submitted to the House naval committee under date of January 15, 1913:

The shipbuilding programs of the principal naval powers indicate an increase in warship construction. The new Russian program and the amendment to the German fleet law are particularly noteworthy. The ship yards are working to their full capacity, and a general activity is manifest.

The all-big-gun battleship has become the definite standard and is now the only type of battleship under construction. The system employed by the United States in mounting all turrets on the center line has been universally copied, and all ships laid down this year, including battle cruisers, are so designed.

The 12-inch gun, so long the standard for battleships, has been discarded in favor of a 13.5 or 14-inch gun for ships now under construction, while a 15-inch weapon is under consideration.

The year has seen the completion of a new type of *Dreadnought*, namely, the *Dante Alighieri*, of the Italian navy, the first ship to be armed with the three-gun turret. This system of mounting guns has also been adopted in the Austrian and Russian navies, while in France a four-gun turret has been proposed.

The battle cruisers that are being built by Great Britain, Germany, Japan and Russia show a steady increase in tonnage; in fact, all new construction, including destroyers and submarines, indicate an increase in displacement.

Mining ships and submarine salvage ships are now found in all the principal navies.

Italy and Austria are the only naval powers that continue to build torpedo boats.

The following are the shipbuilding programs of the various naval powers:

GREAT BRITAIN.

The total naval estimates for 1912–13 amount to $228,430,064, as compared with $216,036,101 for the preceding year, while for 1910–11 the amount was $197,597,906. The total estimate includes a supplementary estimate of $4,817,835 and an increase of the enlisted personnel by 1,500 men.

The actual standard of new construction which the admiralty has in fact followed during recent years has been to develop a 60 per cent. superiority in vessels of the *Dreadnought* type over the German navy on the basis of an existing fleet law.

The shipbuilding program authorized for 1912–13 provides for the following new construction: Four large armored ships, eight lightly armored ships, twenty destroyers, a group of submarines, one coastguard cruiser, four oil-tank steamers, 1 water-tank vessel, and two tugs.

During the year there were completed the battleships *Conqueror* and *Thunderer*, each of 22,500 tons displacement; the *Centurion* and *King George V*, of 24,000 tons, as well as the battle cruiser *Princess Royal*, of 26,350 tons, a sister ship of the *Lion*, and the *New Zealand*, of 18,800 tons.

Of four battleships authorized in 1910 two have been completed, and of those of the 1911 program the *Iron Duke* and *Marlborough* were launched this fall. These ships are of about 27,000 tons displacement. The four battleships of the 1912 program are, according to press reports, to be armed with eight 15-inch guns, to displace 27,000 tons, and have a designed speed of 25 knots. Two of these ships were laid down in October, while the contracts for the other two were awarded in November. The battle cruiser *Tiger*, authorized in 1911, has been laid down and will displace approximately 29,000 tons. All capital ships now building, excepting those of this year's program, will be armed with 13.5-inch guns.

The contracts for the eight lightly armored cruisers were awarded during October. These ships, according to the first lord of the admiralty, are to be "the smallest, cheapest and fastest vessels protected by vertical armor, ever projected for the British navy."

The contracts for the twenty new destroyers have been awarded. It is believed that these vessels will have a displacement of 1,000 tons.

Of the submarines authorized neither the number nor the size has been officially announced.

GERMANY.

The total naval estimate for 1912–13 amounts to $110,715,043, as compared with $107,232,000 for 1911–12.

The fleet law has been amended so as to provide by 1920 a fleet to comprise forty-one battleships, twenty large cruisers, and forty small cruisers, an increase of three battleships and two small cruisers. It is proposed to build six submarines yearly and, by allowing a life of 12 years, to maintain an establishment of seventy-two boats. The amendment further provides for the maintenance in full commission of about four-fifths of the fleet.

The naval appropriation bill for 1912–13 authorized the following new construction: One battleship, one battle cruiser, two small cruisers, twelve destroyers, six submarines and one submarine salvage ship. As

usual, there is an increase in the personnel to meet the increased needs of the service. Provision is made for 282 additional officers and 5,454 enlisted men.

During the year there were completed the battleships *Oldenburg*, of 22,435 tons; the *Kaiser* and *Friedrich der Grosse*, of 24,110 tons, displacement. The battle cruiser *Goeben* has been completed. She has a displacement of 22,632 tons, mounts ten 11-inch guns, and on trials attained a speed of 28.6 knots.

FRANCE.

The total naval appropriation for 1912 amounts to $81,692,832, as compared with $80,371,109 appropriated for 1911.

The shipbuilding program authorized for 1912 provides for the following new construction: Three battleships, nine submarines, and one transport. The original program authorized two battleships, but a third was provided for to replace the *Liberté*.

There has been no addition of capital ships to the fleet during the year, but increased activity has become manifest in all ship yards, and work on the new construction is progressing rapidly. Nine destroyers and several submarines have, however, been completed during the year.

The battleships of the 1912 program will mount ten 13.4-inch guns in center-line turrets. A four-gun turret is under consideration for future ships.

JAPAN.

The total naval estimate for the year 1912–13 amounts to $46,158,216, an increase of $2,926,971 over the estimates for 1911–12. The unexpected balance of the existing appropriation "Expenses for maintaining naval preparation" amounts to $123,839,443, to be expended in six years, up to and including 1916–17. The allotment for maintenance and construction for 1912–13 amounts to $24,144,446, as against $21,768,673 for the year 1911-1912.

During the year the following ships have been completed: The battleships *Settsu* and *Kawachi*, both of 20,800 tons, armed with twelve 12-inch guns; three 4,950-ton cruisers (the *Yahagi*, *Hirado* and *Chikuma*); two 600-ton destroyers, and one submarine.

The battleship *Fuso*, authorized in 1911, has been laid down. She is to have a displacement of approximately 30,000 tons and mount 14-inch guns. Three battle cruisers of the 1911 program have been laid down in Japan. They are of the *Kongo* class, 27,500 tons displacement, armed with 14-inch guns, and a designed speed of 29 knots.

RUSSIA.

The naval estimates for 1912, ordinary and extraordinary expenditures, amount to $84,630,780. This is an increase over the budget as voted last year of $28,061,933.

The naval program as prepared under the direction of the minister of marine and authorized by the duma includes the following items: (1) For new construction, fitting out, and enlargement of ports, etc., $221,450,000. (2) For completion of ships building and current expenses, $403,245,000. Item (1) constitutes the small shipbuilding program which is to be executed in five years.

The new construction includes four battle cruisers, four protected cruisers, thirty-six destroyers and twelve submarines for the Baltic, four protected cruisers for the Black Sea, two protected cruisers and six submarines for the Pacific. It was decided that the annual installments should be asked for as separate yearly credits.

The only addition to the fleet during the year has been the *Novik*, a destroyer of 1,260 tons displacement, with a speed of 36 knots. There are under construction, however, seven battleships of 23,000 tons, four battle cruisers of 28,000 tons, nine destroyers, and six submarines.

ITALY.

The naval appropriation for 1912–13 amounts to $41,893,420. Of this amount $21,722,536 is for the maintenance of existing vessels and for new construction now in hand or to be commenced.

The naval appropriation law does not specify the number or type of ships to be laid down, this being left to the discretion of the Navy Department, but the following new construction has been decided upon: Two battleships, six destroyers, six torpedo boats and six submarines.

During the year there were completed the battleship *Dante Alighieri*, of 18,600 tons displacement, mounting twelve 12-inch guns in four center-line turrets; one scout cruiser, of 3,220 tons, besides several torpedo craft and submarines.

There are under construction, besides the two battleships provided for this year, five battleships, two scout cruisers and several torpedo craft and submarines.

AUSTRIA.

The total naval estimates for 1912 amount to $28,167,714. Referring to the program adopted by the Austro-Hungarian delegations in the autumn of 1910, which authorized an expenditure of $63,417,200 for shipbuilding in six installments during the years 1911 to 1916, inclusive, the amount apportioned for this year for new construction is $13,601,000, which is to be expended on the ships now building. The amount apportioned for 1912 ($13,601,000) was increased by the granting of an extraordinary credit of $8,120,000 on October 14, 1912, by the delegations. The total amount appropriated for the Navy for the year 1912 is, therefore, $36,287,714. The only new construction provided for this year is one mining vessel of 1,000 tons displacement.

During the year the battleship *Viribus Unitus*, of 20,010 tons displacement, mounting twelve 12-inch guns in four center-line turrets, has been added to the fleet. Three battleships, three small cruisers, six destroyers, twelve torpedo boats and seven submarines are under construction.

PROGRAMS FOR 1913–14.

The programs for 1913–14, so far as they have been determined or published, are as follows:

GREAT BRITAIN.

The program for 1913–14 has not as yet been published, but the Government has been committed by a statement of the first lord of the Admiralty to the laying down during the year of at least five first-class armored ships. This number will be augmented by the proposed gift of £7,000,000 by the Canadian Government for the construction of three first-class ships and by the acceptance of the offer of the federated Malay states of a first-class armored ship to cost two and one-half million pounds, payable within five years. The date for the construction of these gift ships has, however, not been made public. Provisions for the construction of scout cruisers, destroyers and submarines will undoubtedly also be made.

According to recent press reports ("London Daily Telegraph" of Jan. 6, 1913), the naval estimates for 1913–14 will reach an aggregate of nearly $243,325,000. This represents an increase of between $19,466,000 and $24,332,500 over the estimates for 1912–13.

GERMANY.

The total naval estimates for 1913–14 submitted to the reichstag in the latter part of November, 1912, amount to $111,288,618. The ordinary recurring expenditure is $46,935,805; the nonrecurring ordinary expenditure is $52,179,113; the extraordinary expenditure is $12,173,700. This is an increase over last year's (1912–13) final estimates (the ordinary estimates and the supplementary estimates being taken together) of $573,574.

Increase of personnel is provided as follows: Two hundred and twenty-three additional officers and 6,125 enlisted men. The total strength of the personnel of the Navy will in 1913 be 3,394 officers and 69,495 men.

The provisions for new ships are according to the program laid down in the fleet law and provide for the construction of two battleships, one battle cruiser, two small cruisers, one gunboat, one torpedo-boat flotilla (12 boats), and $4,760,000 for submarine construction and experiment. The construction of a new imperial yacht was also appropriated for.

FRANCE.

The naval estimates for 1913–14 submitted to the chamber of deputies carries a total appropriation of $89,028,626. Of this amount $22,946,738 is for new construction and provides for the laying down of two battleships, three destroyers, three submarines and one river gunboat. It also includes the first installments for the two battleships provided in the fleet law for 1914. Those two ships were to have been begun January 1, 1914, but recent advices indicate that at least one will be laid down at Lorient October 1, 1913.

A further increase in the present shipbuilding program is under discussion.

JAPAN.

The naval estimates for 1913–14 have not yet been submitted. A new shipbuilding program has been under discussion for some time, but the details are not known. Press reports vary as to the number of capital ships; various advices indicate that seven battleships and six battle cruisers, two to be laid down yearly, will be asked for, while others state that on account of economical reasons three ships only of the *Fuso* type, to be completed in five years, will be demanded.

RUSSIA.

From press reports the naval estimates for 1913–14 amount to $119,229,250, which includes $36,012,100 for the objects of the new program, $9,343,680 for completing the four battleships of the *Gangut* class, and $14,599,500 for the ships building for the Black Sea. The new program calls for the construction of the following units: Four battle cruisers, eight cruisers, thirty-six destroyers and twelve submarines.

AUSTRIA.

From press reports the naval estimates for 1913 recently passed by the delegations amount to $28,939,000. Of this amount $13,885,200 constitutes the extraordinary credit for new construction allotted for the year 1913 and $15,054,000 the ordinary expenditure. The personnel is hereby increased as follows: One rear admiral, 3 captains, 5 commanders, 31 lieutenants, 12 midshipmen, 5 medical officers, 27 engineers, 6 paymasters, and 1,500 petty officers and men. The strength will be increased from 14,000 men to 21,000 men in 1916.

According to the "London Times" of January 6, 1913, Admiral Count Moulecuccoli's demand for the immediate construction of a new *Dreadnought* division in place of the old 5,600-ton battleships of the *Monarch* class was not accepted, but was referred to a subsequent conference, which is expected to meet a few weeks hence. It is suggested that the decision will then be taken to begin the building of the new *Dreadnoughts* in 1914, instead of 1915, as was originally planned.

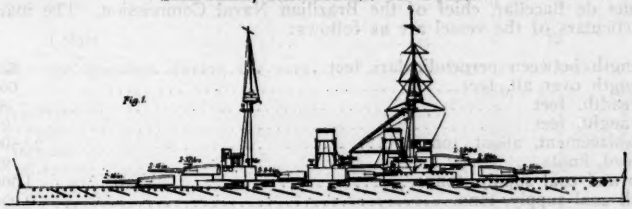
ITALY.

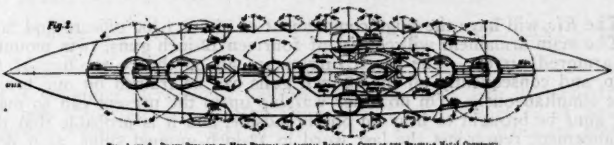
The naval estimates have not yet been made public. Two battleships are to be begun during the year, and it is reported that there is a proposal to lay down two additional vessels in certain circumstances.—"Army and Navy Register."

BRAZIL.

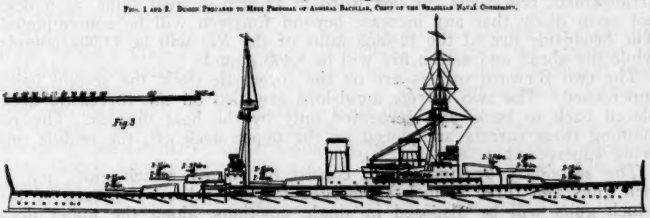
THE BRAZILIAN BATTLESHIP *RIO DE JANEIRO* AND ALTERNATIVE DESIGNS.

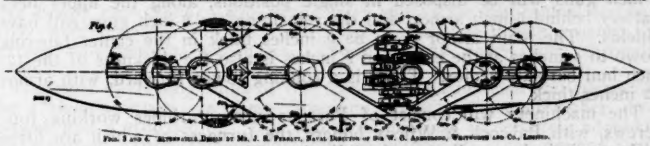
Sir W. G. Armstrong, Whitworth & Co., Limited, Elswick Shipyard, Newcastle-on-Tyne.



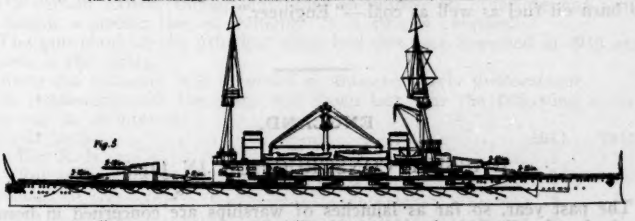


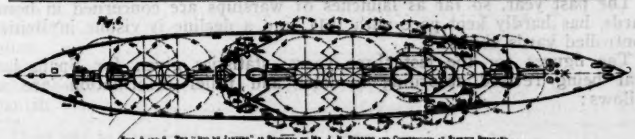
Figs. 1 and 2. Designs Prepared to Meet Proposal of Admiral Bacellar, Chief of the Brazilian Naval Commission.





Figs. 3 and 4. Alternative Designs by Mr. J. H. Perrett, Naval Director of Sir W. G. Armstrong, Whitworth and Co., Limited.





Figs. 5 and 6. The "Rio de Janeiro" as Designed by Mr. J. H. Perrett and Constructed at Elswick Shipyard.

From "Engineering."

BRAZILIAN BATTLESHIP RIO DE JANEIRO.

The Brazilian battleship *Rio de Janeiro* was launched from the Elswick shipyard of Sir W. G. Armstrong, Whitworth & Co., Limited, on January 22, by Madame Huet de Bacellar, wife of his Excellency, Admiral Duarte Huet de Bacellar, chief of the Brazilian Naval Commission. The main particulars of the vessel are as follows:

Length between perpendiculars, feet	632
Length over all, feet	668
Breadth, feet	89
Draught, feet	27
Displacement, about, tons	27,500
Speed, knots	22
Normal coal supply, tons	1,500
Full coal supply, tons	3,000

The *Rio* will have the huge complement of about 1,100 officers and men.

The main armament will consist of fourteen 12-inch guns, twin mounted in armored turrets. The seven turrets are all on the center line of the ship, and consequently all the 12-inch guns can be trained on one broadside simultaneously. On no other warship up to the present can so many big guns be brought to bear on one broadside, and it is probable that this arrangement represents the last word in 12-inch gunned ships, as it does not seem likely that any increase beyond fourteen will be contemplated. The broadside fire of the 12-inch guns of the *Rio* will be 11,900 pounds, while the ahead and astern fire will be 3,400 pounds.

The two forward turrets are on the forecastle deck, the second being superposed. The two turrets amidships are also on the forecastle deck, placed back to back, and separated only by the boat derrick. The remaining three turrets are placed on the upper deck aft, the middle one being superposed.

The secondary armament will consist of twenty 6-inch guns, ten 3-inch guns and three 21-inch submerged torpedo tubes. Fourteen of the 6-inch guns will be disposed in single positions, along the upper deck battery behind 6-inch armor, and the remaining six 6-inch guns will have shields. The main armor is to be 9 inches thick in the center tapering down to 4 inches at the ends, and 9 inches is also the thickness of the 12-inch bun barbette armor. There is a conning tower forward, with armor 12 inches thick.

The machinery will consist of Parsons steam turbines working four screws, with Babcock & Wilcox boilers, the furnaces of which are fitted to burn oil fuel as well as coal.—"Engineer."

ENGLAND.

WARSHIP CONSTRUCTION IN 1912.

The past year, so far as launches of warships are concerned in home yards, has hardly kept pace with 1911, and a decline is visible in British controlled yards abroad.

The figures for the last three years—statistics given for Spain last year being revised according to later and fuller information—are as follows:

Capital Ships Launched.

	1910.	1911.	1912.
British home yards	4	8	6
Yards abroad under British control:			
Spain	0	0	1
Russia	0	4	0
Totals	4	12	7

Foreign launches during the same period have been as follows:

	1910.	1911.	1912.
Austrian	1	1	2
French	0	2	2
German	2	4	3
Italian	1	3	0
Japanese	1	1	1
U. S. A.	1	4	2
Totals	6	15	10

Notes to Table of Capital Ships Laid Down in 1912.

It is becoming increasingly difficult to obtain exact data in connection with new ships intended for the British or German navies or of South American Republics and other minor States. All figures given are therefore open to possible variation.

During the past year nothing has occurred to indicate the necessity of larger calibers than 13.5 inches or 14 inches. Roughly, the situation is twofold—a non-technical public thinking in calibers and a technical few thinking in measures of efficiency per ton of armament carried. Between these two ideals there is necessarily a wide divergence.

A Greek battle cruiser, the contract for which would have been commenced by the German Vulcan Company, has been delayed by a decision of the Greek Admiralty to build a much more powerful vessel. The proposed ship has been redesigned from 16,000 tons odd to 19,500 tons.

In connection with the German Navy it is not impossible that the battleship *Ersatz Brandenburg* will have Diesel motors for her central engine. They were proposed for her earlier sisters, but fell through owing to certain constructional difficulties. The plan may have fallen through again.

The most interesting ships of the year are the American battleships of the *Oklahoma* class. In these "medium protection" is altogether discarded, and a principle of "13½ inches or nothing" is definitely adopted. To a certain extent, though not quite so boldly, all other designs tend to follow a similar line of thought. It is strictly practical.

The gun plans of the principal ships laid down or launched in 1912 are shown in the plates.

American influence will be noted as almost entirely predominant.

In connection with the ships laid down last year the following statistics may be of interest:

British yards—	1911.	1912.
For R. N.	5	7
For other Powers	6	0
German	4	2
French	2	3
Japanese	1	3
Italian	2	2
Russian	*3	*4
United States	2	2
Spanish	0	1

* These may be considered as semi-British orders.

CAPITAL SHIPS LAUNCHED IN 1912.

Name.	Builder.	Launched.	Normal displacement.	Armament, guns and torpedo tubes	H.P.	Speed.	Machinery.	Boilers.	Builders of machinery.
			Tons.			Knots.			
BRITISH—									
Ajax	Scott's	March	28,000	10 13.5in., 20 4in., 5 21in. t.t.	31,000	21	Parsons turbine	Babcock	Scott's
Audacious	Cammell, Laird	September	23,000	10 13.5in., 20 4in., 5 21in. t.t.	31,000	21	Parsons turbine	Yarrow	Cammell, Laird
Queen Mary	Palmer	March	28,560	8 13.5in., 16 4in., 5 21in. t.t.	80,000	28	Parsons turbine	Yarrow	Clydebank
Iron Duke	Portsmouth Yard	October	28,000	10 13.5in., 16 6in., 5 21in. t.t.	33,000	21	Parsons turbine	Babcock	—
Marlborough	Devonport Yard	October	28,000	10 13.5in., 16 6in., 5 21in. t.t.	33,000	21	Parsons turbine	Yarrow	Hawthorne
AUSTRIAN—									
Tegetthof	Stab. Tecnico	March	20,000	12 12in., 12 6in., 4 21in. t.t.	25,000	21	Parsons turbine	Yarrow	Stab. Tecnico
P. Eugen	Pola	November	20,000	12 12in., 12 6in., 4 21in. t.t.	25,000	21	Parsons turbine	Yarrow	Stab. Tecnico
FRENCH—									
Paris	La Seyne	28 September	23,467	12 12in., 22 5.5in., 4 18in. t.t.	28,000	21	Parsons turbine	Belleville	La Seyne
France	St. Nazaire	November	23,467	12 12in., 22 5.5in., 4 18in. t.t.	28,000	21	Parsons turbine	Niclausse	St. Nazaire
GERMAN—									
K. Albert	Schichau, Danzig	April	24,500	10 12.2in., 14 6in., 6 22in. t.t.	25,000	20-21	Parsons turbine	Schulz T.	Schichau
P.R. Luitpold	Krupp	February	24,500	10 12.2in., 14 6in., 6 22in. t.t.	25,000	20-21	Parsons turbine	Schulz T.	Krupp
Seydlitz	Blohm and Voss	March	24,000	10 12.2in., 14 6in., 6 22in. t.t.	63,000	25.5	Parsons turbine	Schulz T.	Blohm and Voss
JAPANESE—									
Kongo	Vickers	18 May	27,500	8 14in., 16 6in., 8 t.t.	68,000	27	Parsons turbine	Yarrow	Vickers
Hi Yei	Yokosuka	November	27,500	8 14in., 16 6in., 8 t.t.	68,000	27	Parsons turbine	Miyabara	
SPANISH—									
Espana	Ferrol	September	15,700	8 12in., 20 4in., 3 18in. t.t.	15,500	19.5	Parsons turbine	Yarrow	Vickers, &c.
U.S.A.—									
New York	New York Yard	October	27,000	10 14in., 21 5in., 4 21in. t.t.	28,100	21	Reciprocating	Babcock	Cramp
Texas	Newport News	May	27,000	10 14in., 21 5in., 4 21in. t.t.	28,100	21	Reciprocating	Babcock	Newport News

SMALL SHIPS LAID DOWN IN 1912.

Name.	Builder.	Laid down.	Normal displacement.	Armament.	H.P.	Speed.	Machinery	Boilers.	Builders of machinery.
			Tons.			Knots.			
BRITISH—									
Nottingham	Pembroke Yard	June	5400	8 6in., 2 21in. t.t.	22,000	24.75	Parsons turbine	Yarrow	—
Birmingham	Elswick	(1913)	5400	9 6in., 2 21in. t.t.	22,000	24.75	Parsons turbine	Yarrow	—
Lowestoft	Chatham Yard	June	5400	9 6in., 2 21in. t.t.	22,000	24.75	Parsons turbine	Yarrow	—
Brisbane	Sydney	(1913)	5400	9 6in., 2 21in. t.t.	22,000	24.75	Parsons turbine	Yarrow	—
Lightly Armoured, 1	Beardmore						Parsons turbine		
,, 2	Beardmore						Parsons turbine		
,, 3	Beardmore						Parsons turbine		
,, 4	Fairfield						Brown Curtis t.		
,, 5	Vickers	December	About 3000	Not known	—	—	Parsons turbine	Yarrow	—
,, 6	Vickers						Parsons turbine		
,, 7	Chatham Yard						Brown Curtis t.		
,, 8	Devonport Yard						Brown Curtis t.		
AUSTRIAN—									
Novara	Fiume	July	3600	9 4.1in., 2 18in. t.t.	27,000	27	Parsons turbine	Yarrow	—
BRAZILIAN—									
Javary									
Madeira	Vickers	August	1230	2 6in., 2 4.7	(?)	11.5	Reciprocating	Yarrow	Vickers
Solimoes									
GERMAN—									
E. Irene	Weser, Bremen	(1912)	4700	12 4.1in., 2 21in. t.t.	25,500	28	Diesel	—	Weser
E. P. Wilhelm	Kiel Yard	(1913)	4700	12 4.1in., 2 21in. t.t.	28,500	28	Turbine	Schulz T.	

NOTE.—Diesel motors to the Ernste Irene are somewhat uncertain, and steam may be fitted after all. In any case it is doubtful whether more than part of the power will be from oil engines.
The Brazilian vessels are merely river monitors. All the others recorded are cruisers.
In addition to the ships mentioned, Russia, Spain, Turkey, and China are all reported to have laid down or ordered various small gunboats.

SMALL SHIPS LAUNCHED IN 1912.

Name.	Builder.	Launched.	Normal displacement.	Armament.	H.P.	Designed speed.	Machinery.	Boilers.	Builders of machinery.
			Tons.			Knots.			
BRITISH—									
Southampton	Clydebank	May	5400	8 6in., 2 21in. t.t.	22,000	26	Curtis Y.	Yarrow	Clydebank
Dublin	Beardmore	April	5400	8 6in., 2 21in. t.t.	22,000	26	Parsons turbine	Yarrow	Beardmore
Fearless	Pembroke Yard	June	3300	10 4in., 3 21in. t.t.	18,000	25	Parsons turbine	Yarrow	Hawthorne
AUSTRIAN—									
Helgoland	Danubius Werft	November	3500	9 4in., 3 18in. t.	25,000	27	Parsons turbine	Yarrow	Danubius W.
Saida	Triest, W.C.N.	October	3500	9 4in., 3 18in. t.	25,000	27	Parsons turbine	Yarrow	Triest, W.C.N.
CHINESE—									
Fei Hung	N.Y. Shipbuilding	(1913)	3600	2 6in., 4 4in., 18in. t.t.	6,500	20	Parsons turbine	Thornycroft	N.Y. Shpbldg.
DUTCH—									
Rinio	Amsterdam	(1913)	540	4 4.4in.	1,200	16	Diesel	Nil	—
Prins	Amsterdam	(1913)	540	4 4.1in.	1,200	16	Diesel	Nil	—
Gruno	Amsterdam	(1913)	540	4 4.1in.	1,200	16	Diesel	Nil	—
GERMAN—									
Karlsruhe	Krupp	November	About 5000	12 4.1in., 50 cal. 2 22in. t.t.	25,000	28	Turbine	Schulz T.	Krupp
Rostock	Howaldt	November	5000	12 4.1in., 50 cal. 2 22in. t.t.	25,000	28	Turbine	Schulz T.	Howaldt
ITALIAN—									
Marsala	Castellamare Yard	March	3600	6 4.7in., 2 18in. t.t.	25,000	27	Parsons turbine	Blechynden	(?)
Libia	Ansaldo	November	3600	2 6in., 6 4.7in., 3 18in. t.t.	12,000	22	Reciprocating	Niclausse	Ansaldo
Sebastiano Cabot	Palermo	(1913)	810	6 12-pdr.	2,000	13	—	—	—

CAPITAL SHIPS LAID DOWN IN 1912.

Name.	Builder.	Laid down.	Normal displacement.	Armament.	H.P.	Designed speed.	Machinery.	Boilers.	Builders of machinery.
			Tons.			Knots.			
BRITISH—									
Iron Duke	Portsmouth Yard	January	25,000	10 13.5in. A., 16 6in., 8 21in. t.t.	(†)	22	Parsons turbine	Babcock	Cammell, Laird
Marlborough	Devonport Yard	January	25,000	10 13.5in. A., 16 6in., 8 21in. t.t.	(†)	22	Parsons turbine	Yarrow	Hawthorn, L.
Delhi	Vickers	May	25,000	10 13.5in. A., 16 6in., 6 21in. t.t.	(†)	22	Parsons turbine	Yarrow	Vickers
Benbow	Beardmore	June	25,000	10 13.5in. A., 16 6in., 6 21in. t.t.	(†)	22	Parsons turbine	Babcock	Beardmore
Tiger	Clydebank	June	28,500	8 13.5in. A., 10 6in., 2 21in. t.t.	100,000	21	Parsons turbine	Babcock	Clydebank
Queen Elizabeth	Portsmouth Yard	November	25,000*	8 13in. (†), 6in. (†) t.t.	(†)	25	Parsons turbine	Babcock	(†)
Warspite	Devonport Yard	November	25,000*	8 13in. (†), 6in. (†) t.t.	(†)	25	Parsons turbine	Yarrow	(†)
CHILE—									
Al Latorre	Elswick	June	28,000	10 14in.‡ 20 4·7in., 4 21in. t.t.	40,000	23	Parsons turbine	Yarrow	Vickers
FRENCH—									
Bretagne	Brest	July	23,500	10 13.4in., 22 5.5in., 4 18in. t.t.	29,000	21	Parsons turbine	Belleville	La Seyne
Lorraine	St. Nazaire	July	23,500	10 13.4in., 22 5.5in., 4 18in. t.t.	29,000	21	Parsons turbine	Normand	St. Nazaire
Provence	Lorient	July	23,500	10 13.4in., 22 5.5in., 4 18in. t.t.	29,000	21	Parsons turbine	Guyot	La Seyne
GERMAN—									
E. Brandenburg	Kiel Yard	(1913)	27,000*	† 8 14in., 12 6in., 6 21in. t.t.	(†)	24	(†)	Schuh T.	
E.K. Augusta	Schichau-Danzig	September	30,000*	† 8 14in., 12 6in., 6 22in. t.t.	100,000	20.5	Parsons turbine	Schuh T.	Schichau
ITALIAN—									
Duilio	Castellamare	April	21,500	13 12in., 18 6in. (†) tubes	34,000	22.5	(†) T.	Yarrow	Ansaldo
A. Doria	Spezia	March	21,500	13 12in., 18 6in. (†) tubes	34,000	22.5	(†) T.	Yarrow	Ansaldo
JAPANESE—									
Haruna	Kawasaki Co.	March	27,500	8 14in., 16 6in., 8 21in. t.t.	68,000	27	Curtis turbine	Miyabara	Kawasaki
Kirishima	Mitsu Bishi Co.	March	27,500	8 14in., 16 6in., 8 21in. t.t.	68,000	27	Parsons turbine	Miyabara	Mitsu Bishi
Fuso	Kure	March	31,200	10 14in., 16 6in. (†) t.t.	45,000	22.5	Parsons turbine	Miyabara	(†)
RUSSIAN—									
Ismail	Galerni	December	23,000	9 14in., 20 4.7in. (†) t.t.	(†)	27	(†) T.	Yarrow	Baltic Works
Kinburn	Baltic Works	December	23,000	9 14in., 20 4.7in. (†) t.t.	(†)	27	(†) T.	Yarrow	Baltic Works
Borodino	Galerni	December	23,000	9 14in., 20 4.7in. (†) t.t.	(†)	27	(†) T.	Yarrow	Baltic Works
No. 6	Baltic Works	December	23,000	9 14in., 20 4.7in. (†) t.t.	(†)	27	—	Yarrow	Baltic Works
SPANISH—									
Jaime I.	Ferrol	February	15,700	8 12in., 20 4in., 2 18in. t.t.	15,500	19.5	Parsons turbine	Yarrow	Vickers, &c.
SWEDISH—									
Sverige	Gothenburg	(1912)	7,000	4 11in., 8 6in., 2 t.t.	20,000	22.5	(†) T.	Yarrow	Gota Works
U.S.A.—									
Oklahoma	N.Y. Shipbuilding	June	27,000	10 14in., 21 6in. (†), 21in. t.t.	35,000	20.5	Reciprocating	Babcock	N.Y. Shipbg.
Nevada	Fore River Co.	June	27,000	10 14in., 21 6in. (†), 21in. t.t.	35,000	20.5	Curtis turbine	Babcock	Fore River Co.

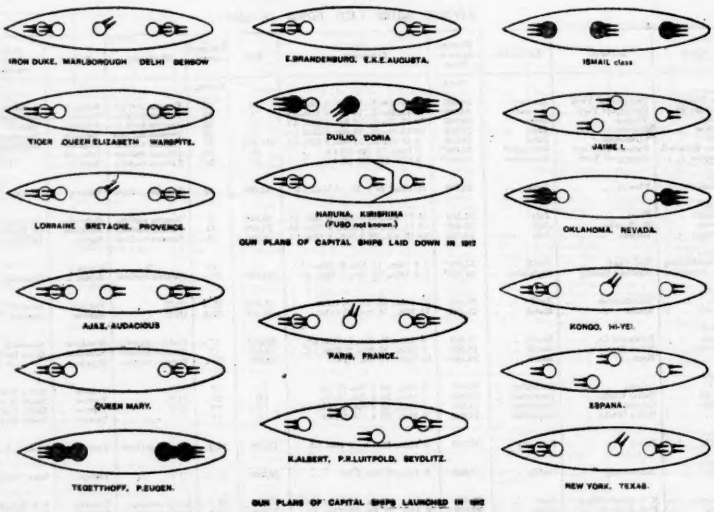
British "13·5 A" is reported to be really 14in. Puso armament also reported as 8-15in. * About. † Probably.

PRINCIPAL TRIALS IN 1912.

Name.	Builder.	Builders of machinery.	Boilers.	Designed for	Trial results. Mean.	Trial results. Maximum.
					30 hrs. at ¾ power. / 8 hrs. at full speed.	
BRITISH—						
Orion	Portsmouth Yard	Parsons turbine by Wallsend	Babcock	27,000 = 21 knots	18,500 = 19.5 / 29,100 = 21	21.21
Thunderer	Thames I.W.	Parsons turbine by Thames I.W.	Babcock	27,000 = 21 knots	18,329 = 19.5 / 27,424 = 20.6	(†) *
Conqueror	Beardmore	Parsons turbine by Beardmore	Babcock	27,000 = 21 knots	19,100 = 19.4 / 28,400 = 23.1	23.1 †
Monarch	Elswick	Parsons turbine by Hawthorn	Yarrow	27,000 = 21 knots	19,129 = / 28,559 = 21.66	—
Lion	Devonport	Parsons turbine by Vickers	Yarrow	70,000 = 28 knots	= 24.6 / = 29	31.7 †
Princess Royal	Vickers	Parsons turbine by Vickers	Yarrow	70,000 = 28 knots	/	32.4
					(†) hrs. at ¾. / Full power.	
Falmouth	Beardmore	Parsons turbine by Beardmore	Yarrow	—	18,576 = / 26,311 = 27.01	— *
Dartmouth	Vickers	Parsons turbine by Vickers	Yarrow	—	18,529 = 24.95 / 23,427 = 25.99	—
Weymouth	Elswick	Parsons turbine by Parsons	Yarrow	—	19,979 = / 25,522 = 25.99	—
Yarmouth	London and G.	Brown Curtis turbines by London and G.	Yarrow	—	= / 24,000 = 26.99	—
					At ¾.	
Active	Pembroke	Parsons turbine by Hawthorn	Yarrow	18,000 = 25 knots	14,382 = / 18,498 = 26.9	— †
Lurcher	Yarrow	Parsons turbine by Yarrow	Yarrow	Designed for 25 kts.	/ = 26.54	— †
GERMAN—						
Oldenburg	Schichau	Reciprocating by Schichau	S. Thornycroft	23,000 = 20.5 knots	(†) / (†) = 22.2	22.2 †
Goeben	Blohm and Voss	Parsons turbine by B. and Voss	S. Thornycroft	70,000 = 27 knots	(†) / (†) = 29.6	32 ‡‡
Magdeburg	Weser	Bergmann turbine by Weser	S. Thornycroft	30,000 = 27 knots	(†) / (†)	27.5 ††
Breslau	Vulcan Co.	A.E.G. (Curtis) turbines by Vulcan	S. Thornycroft	30,000 = 27 knots	(†) / (†)	27.5 ††
ITALIAN—						
					At ¾.	
D. Alighieri	Castellamare	Parsons turbines by Ansaldo	Blechynden	—	21,000 = 21 / 24,000 = 23.5	24.5 ††
JAPANESE—						
Umikaze	Japan	Parsons turbines	Miyabara	—	/ = 32.45	(†) ††
U.S.A.—						
Utah	N.Y. Yard	Parsons turbines by N.Y. Yard	Babcock	23,000 = 20.5 knots	/ = 21.92	22.07
Florida	N.Y. Shipbuilding	Parsons turbines by N.Y. Shipbg.	Babcock	32,000 = 20.5 knots	/ = 21.04	—
					24 hrs. / 4 hrs.	
Wyoming	Cramp	Parsons turbine by Cramp	Babcock	28,000 = 20.5 knots	20,784 = 19.21 / 31,437 = 21.28	22.65

REMARKS.

* Did much better on later trials, but reliable data unprocurable.
† On 6 measured mile runs the speed was practically the same each time.
‡ Since reported to have reached 24.7 with new propellers.
§ Turbines of all have given more or less trouble.
¶ Consumption 1.6 lb. on full power.
** Destroyer to Special Yarrow design.
†† Best measured mile in each case.
‡‡ Maximum speed quite unverified.
§§ Both of these turbines seem well up to contract power on trial, but there is nothing to indicate that they exceeded results here given.
¶¶ Maximum is result of best measured mile.
*** T.B.D. did not reach expectations.



Last year's figures have been corrected in one or two cases where a nominal "laying down" was concerned. For 1912 we have confined ourselves to verified actualities. Hence the exclusion of certain ships officially declared to be "building."

As in 1911, so in 1912, the foreign Power trade has come entirely to this country; but that is somewhat within the chapter of accidents. But for Greece having altered her order, Germany would have shared with us the meager foreign orders for 1912. Excluding the Greek ship already secured, the possibilities of 1913 are as follows: 1 Brazilian, 3 Portuguese, 2 Norwegian; semi-contract probabilities are 3 Spanish and some 8,000-ton Russian armored cruisers. There are bare possibilities of Bulgaria and Peru being in the market, but both these prospects are at present very remote.

Speed Trials.

Some of the principal speed-trial results of the last year are given below. It is necessary, however, to mention that in many cases the results do not always mean maximum even when so recorded. For example, there is a growing practice in the British Navy to confine trials merely to attaining the contract horsepower and speed. Again, in the case of the German Navy certain very high figures get published which are later followed by official figures that are considerably lower. There is some reason to believe that the official figures often represent results at the exact designed horsepower where speed is concerned, and not the ship's actual capabilities. Again, it is frequently difficult to ascertain whether speeds are by patent log or over a measured course. For these reasons we have found it impossible to give a completely uniform table, though we have in every case endeavored to do so, and hope that approximately we have succeeded by the method of tabulating employed.

The principal trials of 1912 include the British *King George V*, but reliable data as to these are impossible to procure, so we have excluded her altogether. The only fact really known is that the ship did extremely well on trials.—"Engineer."

OBITUARY.

ROBERT FORSYTH.

By Chief Engineer George F. Kutz, U. S. N. (Retired).

Robert Forsyth, an associate member of the American Society of Naval Engineers, died at his residence in San Francisco, California, December 18th, 1912, aged 66 years. Thus terminated the career of a forceful man.

Born in Dumfries, Scotland, he, early in life, began his career as a marine engineer in the merchant service under the flag of Great Britain. Coming to the United States in 1870, he engaged with the Pacific Mail S. S. Co. on their side-wheel steamship *Colorado,* plying in Pacific waters with terminals at San Francisco and Hong Kong. For a number of years he was Chief Engineer of the *City of Peking.* During these years he was making a record for ability as an engineer and exhibiting those qualities which always characterized him throughout his life—courage, determination, integrity and zeal for the work upon which he was engaged.

When the Union Iron Works of San Francisco decided to enlarge the range of their activities by engaging in shipbuilding, and particularly in competing with eastern yards in contracts for battleships, cruisers, etc., for the U. S. Navy, Mr. Forsyth became their Engineer-in-Chief, allied with Mr. George W. Dickie, who was superintendent and designer, and James Dickie, a master of ship construction. This combination was a strong one and their work soon placed the Union Iron Works in the front rank of ship and engine builders, among their output being the *Oregon, Olympia, Monterey, Baltimore, Wisconsin* and *Ohio,* besides numerous torpedo craft and submarines. When the Union Iron Works passed into the hands of the present owners, Mr. Forsyth was selected

for the Presidency of the corporation, and for several years administered its affairs. After the earthquake and fire of 1906 his services terminated with the Union Iron Works and he devoted himself for the remainder of his life to his profession as a consulting engineer. In this capacity he numbered among his clients the Atchison, Topeka and Santa Fe Railway, the Pacific Mail S. S. Co., and the American-Hawaiian S. S. Co.

The arduous work of his life told upon his physical condition and for several years past his health has been a source of anxiety. Living according to a strictly limited regime, he maintained his interest if not his activity in the engineering world's work and enjoyed association with his friends up to within two days of his death, the immediate cause of which was heart failure.

BOOKS RECEIVED.

STEAM ENGINEERING, by WILLIAM R. KING, U. S. N., Retired, Principal Baltimore Polytechnic Institute. 450 pages; price, $4.00. Published by JOHN WILEY & SONS, New York.

This book presents, in a simple and concise manner, the principles underlying the make up of a steam-power plant with such construction details as are necessary for a practical knowledge of Steam Engineering. It is written for the student who has not advanced into the higher mathematics, and will be an excellent book to lay the groundwork for the study of more advanced works on engine and boiler design.

The book is systematically arranged and the subjects are very clearly and logically treated. The cuts are excellent and are sufficiently numerous as to assist in a clear understanding of the subject matter.—U. T. H.

NATIONAL TUBE COMPANY'S BOOK OF STANDARDS. 1913. Size 6¾ by 4¼ inches. 559 pages with index. 136 illustrations. Bound in leather. Published by the NATIONAL TUBE COMPANY, Pittsburgh, Pa. Price, $2.00.

The 1913 edition of the Book of Standards has just been received from the press. The present edition, which is the first since 1902, is much larger and more complete than the older one. It is printed on Canterbury Bible paper and, including the binding, is not quite five-eighths of an inch thick and will fit the pocket readily. The information incorporated has made it strictly a pipe handbook and as such it is believed will find an immense use with the trade. The index of the book will be found to be very complete, all headings being thoroughly cross indexed. There are approximately 4,000 references found in the index.

Several pages are devoted to a descriptive article covering

the main process of manufacturing both welded and seamless tubes, also giving information in regard to the threading, durability and physical properties, etc., of both "National" Pipe and Shelby Seamless Steel Tubes. Several pages describe, illustrate and contain tables in regard to lapweld and seamless tubes, upset and expanded, wrought pipe bends, butted and strapped joints, bump joints, valves and fittings including various kinds of nipples and flanges, hand railings and ladders, working barrels, cylinders, Shelby seamless specialties, Shelby seamless cold-drawn trolley poles, tables of various physical properties of Shelby seamless steel tubes, physical properties of carbonic acid gas, Briggs' standard, holding power of boiler tubes, thermal expansion of iron and steel tubes. There are a number of pages which give weights, dimensions, threads per inch, test pressures, sections of joints, specifications, etc., of the various kinds of pipes and tubings made.

ASSOCIATION NOTES.

At a meeting of the Society held at the Navy Department on Monday, December 30, 1912, the ballots cast for candidates for officers of the Society for the year 1913 were counted and the following declared elected:

President,	Captain R. S. Griffin, U. S. Navy.
Secretary-Treasurer,	Lieutenant O. L. Cox, U. S. Navy.
Members of Council:	Rear Admiral John R. Edwards, U. S. Navy.
	Engineer-in-Chief C. A. McAllister, U. S. R. C. S.
	Lieutenant Commander E. L. Bennett, U. S. Navy.

Lieutenant Commander E. L. Bennett, U. S. N., Retiring Secretary-Treasurer, has rendered his financial statement in accordance with the By-Laws of the Society. The books were audited and found to be correct. On December 31, 1913, the total assets of the Society amounted to $9,595.50. There were no liabilities. The numerical strength of the Society was as follows:

Members	413
Associates	332
Subscribers	356
Exchanges	71
Total	1,172

The annual banquet of the Society was held at Rauscher's in the City of Washington, D. C., on the evening of February 22, 1913. About 175 members and guests were present, among whom were several members of both branches of the Congress. The occasion was a most enjoyable one. Mr.

Walter M. McFarland acted as toastmaster and the following gentlemen responded to toasts:

Senator Claude A. Swanson, of Virginia.
Hon. George E. Foss, M. C. of Illinois.
Hon. Steven B. Ayres, M. C. of New York.

The committee in charge was as follows:

Captain W. Strother Smith, U. S. N.
Engineer-in-Chief C. A. McAllister, U. S. R. C. S.
Lieutenant N. H. Wright, U. S. N.
Lieutenant O. L. Cox, U. S. N.

The following members and associates have joined the Society since the publication of the last JOURNAL:

MEMBERS.

Bonvillian, Claude A., Lieutenant, U. S. Navy.
Collins, Marshall, Ensign, U. S. Navy.
Dunn, Charles A., Lieutenant, U. S. Navy.
Evans, Joseph S., Lieutenant, U. S. Navy.
Hedrick, David I., Ensign, U. S. Navy.
Holliday, Seymour E., Lieutenant, U. S. Navy.
Horner, Ralph B., Lieutenant, U. S. Navy.
Leonard, Emeric R., care Bethlehem Steel Co., South Bethlehem, Pa.
Littlehales, George W., 2132 Le Roy Place, Washington, D. C.
Osgood, Wentworth H., Ensign, U. S. Navy.
Sexton, Floyd J., 3d Lieutenant, U. S. R. C. S.
Stewart, Gustavus U., 3d Lieutenant, U. S. R. C. S.
Woods, James S., Lieutenant, U. S. Navy.
Wortman, Ward K., Lieutenant Commander, U. S. Navy.

ASSOCIATES.

Bobadilla, Tomas, Engineer Lieutenant, Argentine Navy, Fore River Shipbuilding Co.
Fullerton, Robert A., 53 Ancaster Drive, Anniesland, Glasgow, Scotland.
Hunt, Howard N., 915 Carolina St., Vallejo, Cal.
Morison, Donald Barns, Hartlepool Engine Works, Hartlepool, England.
Neff, Abner R., Lake Torpedo Boat Co., 714 Evans Building, Washington, D. C.
Southgate, Hugh McLennan, Manager, Government Office, Westinghouse Electric and Manufacturing Co., Hibbs Building, Washington, D. C.
Weaver, Cecil W., Marine Estimator, Pusey and Jones Company, 220 West 20th Street, Wilmington, Del.